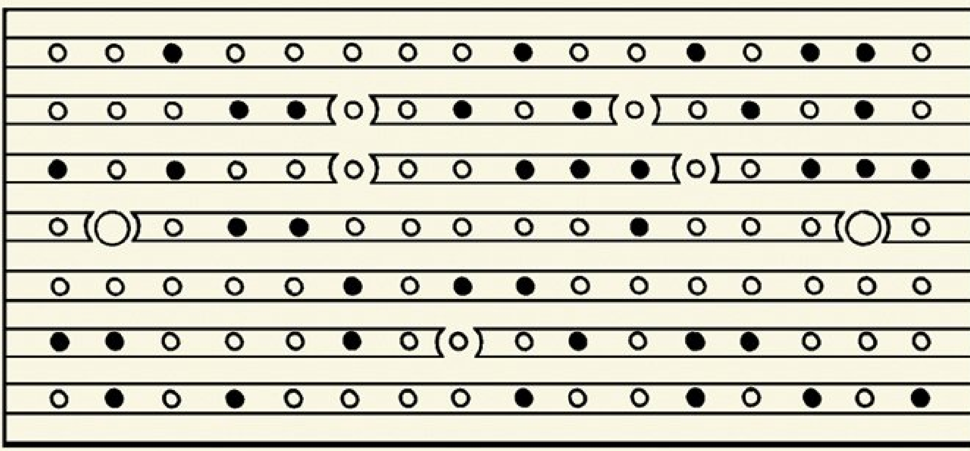
20 SOLID STATE PROJECTS FOR THE CAR AND GARAGE



R. M. Marston

A Newnes Technical Book

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20 Solid State Projects for the Car & Garage

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PREFACE

This volume presents eighteen useful solid-state construction projects for use in the car, and two for use in the garage. The car projects are intended for use in vehicles fitted with 12 volt electrical systems only, and range from simple gadgets such as an ice-warning alarm, a low-fuel-level indicator, and windshield wiper pause controllers, to fairly advanced projects such as a capacitor-discharge ignition system, a lighting fault indicator, an anti-sleep alarm, an electronic tachometer with an add-on excess-speed indicator, and a lighting slave which turns the vehicle's lights on and off automatically when the car is in use. Each project contains detailed information on circuit theory, construction, testing and use.

All circuits have been designed, built, and thoroughly tested by the author. In several cases, the designs have been pre-published in the U.K. or U.S.A., and have subsequently been evaluated by thousands of readers. The C–D ignition system described in Project 1, for example, was first published in the January 1970 issue of *Wireless World*; since that date, two minor changes have been made to the design, which has now been built by tens of thousands of satisfied enthusiasts throughout the world. This particular design has been so successful, in fact, that it is now in production by several companies in Europe and America.

The circuits have all been designed around internationally available semiconductor types, and for ease of construction are wired up on Veroboard panels, which offer all of the advantages but none of the disadvantages of conventional printed circuit boards. Veroboard is readily available throughout the U.S.A. and Europe.

R. M. Marston

Project 1

CAPACITOR-DISCHARGE IGNITION SYSTEM

When this electronic unit is wired up to a car's existing coil and contact-breaker mechanism it greatly improves the shape of the ignition voltage waveform in the spark-plug gaps, and enables a more stable flame-front to be generated in the compressed petrol/air mixture in the cylinders. Better combustion is thus obtained, and engine performance is considerably improved.

The unit, which is known as a capacitor-discharge (C–D) ignition system, confers an impressive list of benefits in terms of engine performance. It has been specially designed to give very easy starting, even under sub-zero conditions, and to give immunity to performance deterioration due to high-speed contact-breaker point bounce, but in addition it also gives quicker engine warm-up, improved acceleration, better high-speed performance, and improved fuel economy. Even more important, it virtually eliminates contact-breaker point burning and wear, gives greatly improved spark-plug life (typically 3 to 5 times longer than in conventional ignition systems), and overcomes the need to adjust contact-breaker and spark-plug gaps with precision.

The C–D ignition unit can be added to any car fitted with a conventional coil ignition system, irrespective of the number of engine cylinders, and is of equal value in touring, sports, and commercial vehicles. Two versions of the unit are described here; one is intended for use in cars with –ve ground electrical systems, and the other for use in cars with +ve ground systems; the units are suitable for use in vehicles with 12 volt systems only.

The units are all-silicon designs, and include three transistors and one silicon controlled-rectifier. The prototype is housed in a 2½ x 6 x 8 in metal case, but these dimensions can be considerably reduced, if required. The units are designed around readily available, or readily adaptable, components, and can be built at moderate cost.

Conventional *v* C–D ignition

To understand why the C–D system gives such a vast improvement in

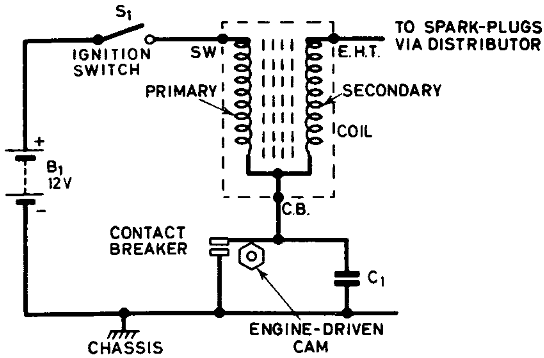


Fig. 1.1. Circuit of conventional inductive-discharge (I–D) ignition system (–ve ground)

engine performance, it is necessary to look at the basic operating principles of both conventional and C–D ignition systems, as follows.

Fig. 1.1 shows the circuit of a conventional, or inductive-discharge (I–D) ignition system. The contact-breaker (C.B.) points are opened and closed by an engine-driven cam, to give correctly synchronized spark generation: When correctly adjusted, the points are closed for 2/3rds and open for 1/3rd of each operating cycle. When the points are closed, current from the battery flows through the coil primary, up to a maximum value of about 4.5 A (determined by the battery voltage and the total resistance, R, of the primary circuit). The current builds up exponentially, with a time constant of L/R seconds, where L = the inductance of the primary winding; typical time constants vary between about 2 ms and 10 ms. As the current builds up, it 'stores' an energy packet of $(L.I^2)/2$ joules, or watt-seconds, in the coil primary.

When the points open, the primary current collapses rapidly, and typically induces a peak potential of 300 to 400 V across the primary coil; this voltage is stepped up (by transformer action) to between 30 kV and 40 kV by induction into the secondary winding, and the stored energy is thence transferred to the spark-plugs by the distributor. C_1 and the coil form a resonant circuit when the points are open, and the secondary voltage typically takes about 125 μs to build up to its peak value.

The I–D ignition system suffers from a number of practical disadvantages. Its high induced primary voltages cause arcing across the C.B. points, which slowly burns away the point surfaces; if the points are not regularly cleaned, engine performance deteriorates. At high engine speeds there is not sufficient time between ignition cycles to enable maximum energy to build up in the coil primary, so the secondary voltage and energy fall off as engine speed increases.

Energy and voltage also decrease when the battery voltage falls as the engine is started.

Fig. 1.2 shows typical I–D ignition performance characteristics and ignition requirements at different engine speeds; the early part of the graph, up to about 100 r.p.m., indicates typical sub-zero starting conditions, when battery voltage falls to about 10 V, compared to a normal value of 13.5 V when under dynamo charge. Note that the system operates with very little safety margin under cold-start conditions, and that the available secondary energy becomes inadequate when engine speeds reach 5,900 r.p.m., so that misfiring starts to occur above this speed. The graph assumes, incidentally, that the engine has not been tuned for several thousand miles; if the engine is freshly tuned, a better high-speed performance is obtained. The graph does not, however, show the effects of high-speed C.B. point bounce, which in practice may cause misfiring to start at an even lower speed than indicated.

Finally, the relatively long secondary voltage rise times of the I–D system (typically about 125 μs) make the ignition system very vulnerable to high energy losses due to fouling of the spark-plug gaps by carbon and oil deposits. These deposits act as a resistance (typically about 2 megohms in cases of bad fouling) across the points. These deposits inevitably absorb some of the applied energy (power-time),

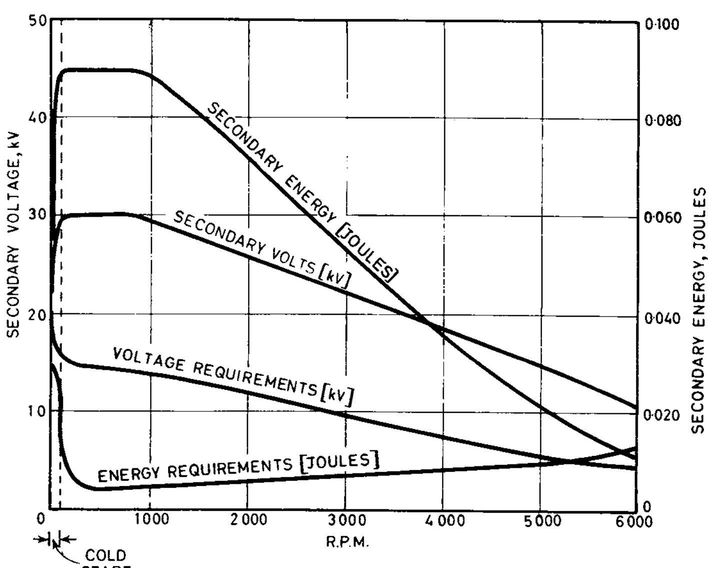


Fig. 1.2. Typical I–D performance and engine ignition requirements curves. Note: Curves assume that battery voltage is normally 13.5 V, falling to 10 V at cold start

and total energy absorption increases in proportion to voltage rise time and fouling resistance. If fouling is bad, all of the applied energy can be absorbed during the early part of the rise time period, leaving zero energy for spark generation; engine misfiring then occurs. Spark-plugs thus need fairly frequent maintenance in I–D systems.

Capacitor-discharge (C–D) ignition systems, on the other hand, suffer from almost none of the snags outlined above. Fig. 1.3 shows the block diagram of the particular C–D ignition that is described later. In

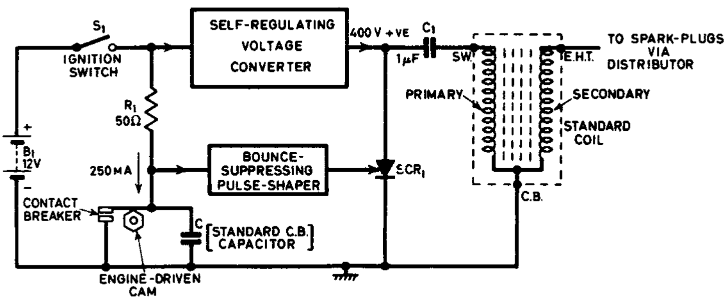
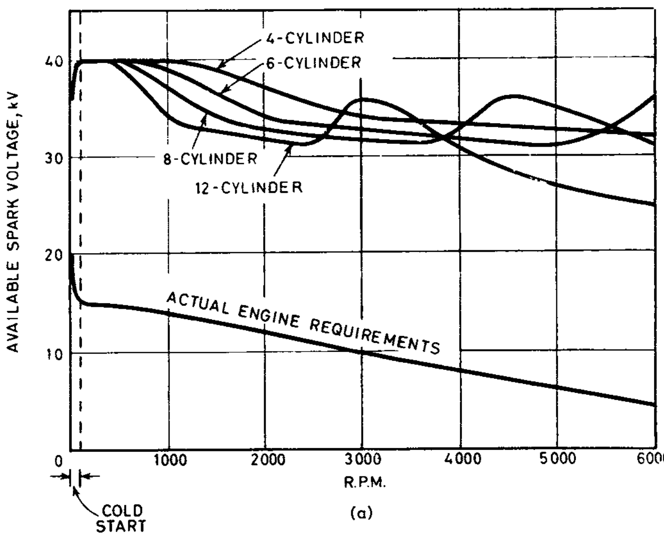


Fig. 1.3. Block diagram of the capacitor-discharge (C–D) ignition system (–ve ground version)

this case, a self-regulating voltage converter is used to charge a storage capacitor C_1 to 400 V, almost irrespective of actual battery potential. When fully charged, this capacitor stores a packet of energy of 0.080 joules (= $[E^2.C]/2$). Silicon controlled-rectifier $S.C.R._1$ is wired between one side of C_1 and ground, and the other side of C_1 is connected to ground via the primary winding of the standard ignition coil. The s.c.r. is triggered from the normal C.B. assembly via a bounce-suppressing pulse shaper. The circuit operates as follows.

When the C.B. is closed, zero input is applied to the pulse shaper, and the s.c.r. is off; a standing current of about 250 mA is passed through the C.B. via R_1 under this condition, to keep the points 'clean' and free from grit. The converter is operating, and charges C_1 to 400 V; the capacitor has a charging time constant of about 1.6 ms.

When the C.B. points first open, the pulse shaper operates and turns the s.c.r. on; the s.c.r. takes only about 2 μs to turn fully on. As the s.c.r. goes on, it shorts the output of the converter, and effectively turns it off. Simultaneously, the s.c.r. shorts one side of C_1 to ground, and the capacitor discharges rapidly into the primary of the coil; the transformer action of the coil steps up the resulting primary voltage to about 40 kV in the secondary winding, and the stored energy of C_1 is thence transferred to the spark-plugs via the distributor; the secondary voltage has a rise time of only a few microseconds. C_1 and the coil form a resonant circuit when the s.c.r. is on, and have a typical resonant



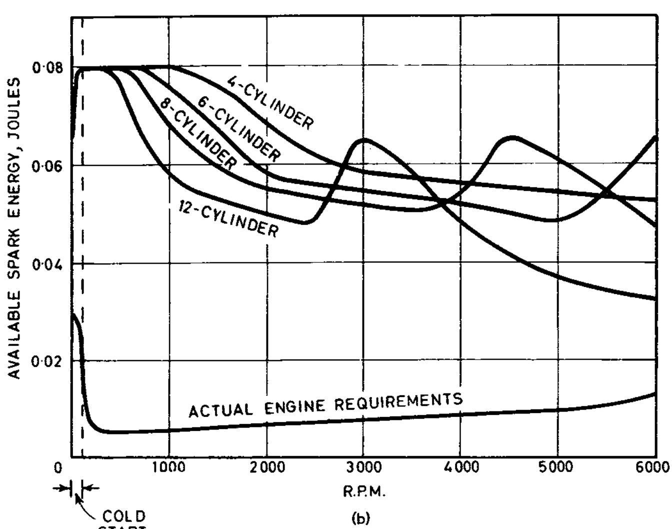


Fig. 1.4. Measured performance curves of the C–D ignition system when fitted to different types of engine.
Note: Curves assume that battery voltage is normally 13.5 V, falling to 10 V at cold start

frequency of about 1,600 Hz, giving a period of roughly 600 μs; at the instant that the s.c.r. fires, therefore, the coil primary voltage rises (in about 2 μs) to 400 V, but 300 μs later the voltage falls to zero as the circuit oscillates; as the voltage falls to zero, the s.c.r. automatically turns off, and the oscillating action ceases. Once the s.c.r. has turned off, the voltage converter re-starts and begins to recharge C_1, even though the C.B. points may still be open; the s.c.r. remains off until the instant that the C.B. points open initially on the following ignition cycle. Note that the primary coil voltage is isolated from the C.B. terminals, which are thus subjected only to the moderately low voltages of the car battery.

The advantages of the C–D ignition system should at this stage be self-evident. Arcing of the C.B. points is eliminated, so point life is greatly increased. The short rise time of the secondary voltage minimizes energy losses due to spark-plug fouling, and thus virtually eliminates the need for plug maintenance and greatly increases useful plug life. The ignition is immune to incorrect firing due to C.B. point bounce. Charge and discharge times of the energy storage capacitor are short, so good sparks are generated up to very high engine speeds. Finally, the available spark energy and voltage is not dictated by battery voltage, so the system gives very easy starting characteristics.

Fig. 1.4a shows the actual spark voltage performance of the prototype C–D system at different engine speeds, when fitted to different types of engine, together with worst-case ignition voltage requirements, and Fig. 1.4b shows the energy generating performance of the system. Note that both the available voltage and energy are well in excess of engine needs under all operating conditions. Starting and high speed characteristics are particularly good when compared to conventional I–D systems.

The practical circuits; how they work

The full circuit of the –ve ground version of the practical C–D ignition system is shown in Fig. 1.5. C_{1a} and C_{1b} form the 1 μF energy storage capacitor. Q_1–Q_2 and T_1 and the D_3–D_6 bridge rectifier form the self-regulating voltage converter. Q_3 and its associated network form the bounce-suppressing pulse shaper, which fires the s.c.r. via its gate and C_3.

The voltage converter section operates as follows: Q_1 and Q_2 act like an astable multivibrator, using the halves of the centre-tapped primary of T_1 as collector loads. Circuit action is such that Q_1 is on when Q_2 is off, and vice versa.

Suppose that, at the instant that power is first applied to the circuit, Q_1 is on and Q_2 is off. As Q_1 goes on, its collector drops to ground

volts, and the collector of Q_2 swings up to 24 V +ve (by the autotransformer action of T_1) and drives Q_1 base hard on via R_8. As Q_1 goes on and draws current through its half of T_1 primary, T_1 core starts to saturate; eventually, after about 10 ms, saturation is complete, and the autotransformer action ceases; Q_2 collector then drops rapidly towards 12 V, and at the same time Q_1 starts to come out of saturation and its collector rises towards 12 V and starts to drive Q_2 on via R_7; regenerative action thus takes place between Q_1 and Q_2, and Q_1 turns sharply off (its collector rising to 24 V) and Q_2 turns sharply on (its collector falling to ground volts), thus reversing the core currents of T_1 and starting another saturation cycle, in the reverse direction to the first. Eventually, after another 10 ms or so, the transformer saturates in this new direction, and the transistors again change state, thus starting the whole cycle over again.

Thus, Q_1 and Q_2 act like a free-running multivibrator, and generate a series of 24 V (approximately) square waves at each collector, at a frequency of roughly 50 Hz. In practice, however, the inductive nature of T_1 causes the early part of each square wave to shoot above the normal flat top; R_{11}–R_{12} and zener diodes ZD_1 and ZD_2 are used to limit this overshoot to 28 V peak, via collector-base feedback, irrespective of battery voltage. T_1 then steps the square waves up to 400 V peak at the secondary winding, and this voltage is then converted to d.c. via the D_3–D_6 bridge rectifier, and is thence used to charge C_1. It is this overshoot regulation that gives the ignition system its good cold-starting characteristics. R_6 gives the circuit a degree of protection in the event of the battery voltage (under dynamo charge) rising above 15 V, and at the same time reduces the C_1 voltage at high engine speeds.

It should be noted that, although the converter oscillates at a natural frequency of only 50 Hz, it is in fact capable of giving good spark generation at C.B. frequencies in excess of 660 Hz, i.e., above 20,000 r.p.m. in a 4-cylinder engine, and above 10,000 r.p.m. in an 8-cylinder engine. The reason for this is as follows.

At the moment that the C.B. points first open in each ignition cycle, $S.C.R._1$ is triggered on and shorts the output of the converter, so Q_1 and Q_2 effectively stop oscillating; 300 μs later, the s.c.r. automatically turns off, so Q_1 and Q_2 start oscillating again; the start of the first half-cycle of each converter operation is thus synchronised by the C.B. At C.B. frequencies above about 100 Hz, therefore, the converter starts into a half-cycle each time the s.c.r. turns off, but the half-cycle is ended prematurely when the s.c.r. goes on again as the C.B. opens; a new half-cycle then starts when the s.c.r. turns off again 300 μs later. The operating frequency of the converter thus synchronizes automatically to half that of the C.B. under this condition. Only a fraction of one natural half-cycle is needed to charge C_1 to a useful value, so

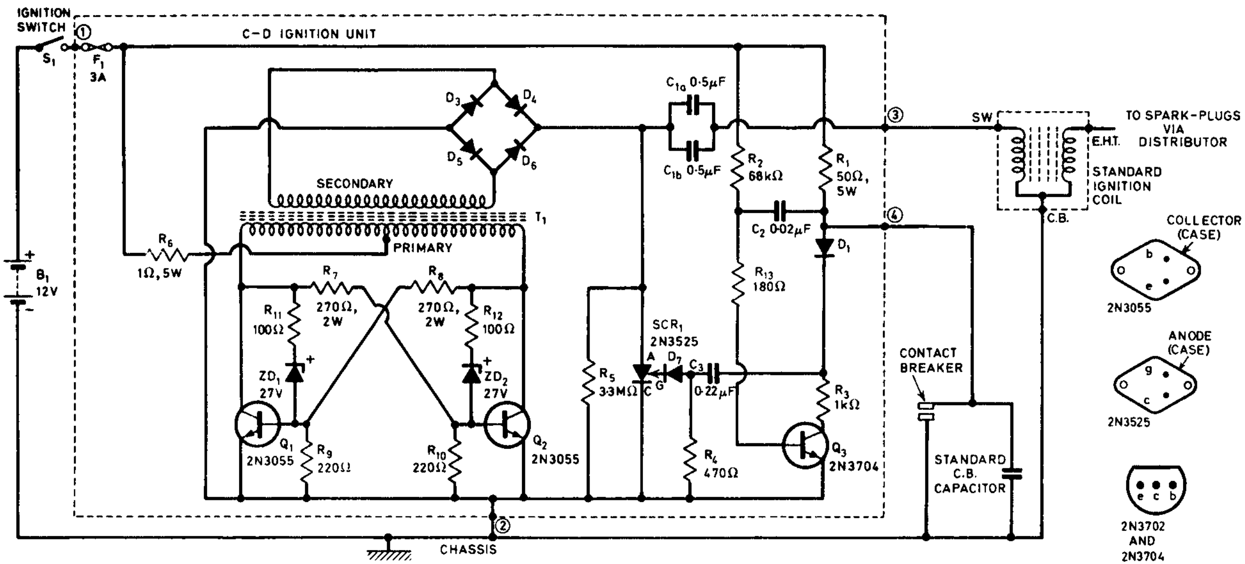


Fig. 1.5. Circuit and connections of the –ve ground version of the unit

Components list (Figs. 1.5 and 1.6)

R_1 =	50 Ω,	5 W	wire-wound
R_2 =	68 kΩ,	½ W	
R_3 =	1 kΩ,	½ W	
R_4 =	470 Ω,	½ W	
R_5 =	3.3 MΩ,	½ W	
R_6 =	1 Ω,	5 W	wire-wound
R_7 =	270 Ω,	2 W	
R_8 =	270 Ω,	2 W	
R_9 =	220 Ω,	½ W	
R_{10} =	220 Ω,	½ W	
R_{11} =	100 Ω,	½ W	
R_{12} =	100 Ω,	½ W	
R_{13} =	180 Ω,	½ W	
C_{1a} =	0.5 μF,	600 V,	paper or Mylar
C_{1b} =	0.5 μF,	600 V,	paper or Mylar
C_2 =	0.02 μF,	50 V,	Mylar
C_3 =	0.22 μF,	50 V,	Mylar

Q_1–Q_2 = 2N3055 (R.C.A. or Motorola)
Q_3 = 2N3702 (Texas) on +ve ground version
or
2N3704 (Texas) on –ve ground version
D_1,D_7 = 1N4001 or similar
D_2 = 1N4001 or similar (used on +ve ground version only)
D_3–D_6 = 1N4005 or similar
ZD_1–ZD_2 = 27 V, 5%, 400 mW zener diode
SCR_1 = 2N3525 (R.C.A.)
F_1 = 3 A fuse
T_1 = L.T. or battery charger transformer,
15:1 ratio at 30 VA (see text).
Hook-up wire, Veroboard, metalwork, etc.

good sparks are generated up to very high engine speeds (see Fig. 1.4).

The C.B. bounce-suppressing and pulse-shaping section of the unit operates as follows. When the C.B. points are closed, a standing current of about 250 mA is passed through the points (to keep them clean) via R_1; the $R_1-D_1-C_2$ junction is at ground volts, and the R_2-C_2 junction is grounded via R_{13} and Q_3 base-emitter junction. Assume that C_2 and C_3 are fully discharged.

At the instant that the C.B. points open, 12 V appears across the points, and C_3 charges rapidly via R_1-D_1 and the s.c.r. gate and turns the s.c.r. on. Simultaneously, C_2 charges rapidly via R_1-R_{13} and Q_3 base, and Q_3 turns on.

At the instant that the points close again, the $R_1-D_1-C_2$ junction once more drops to ground volts; C_3 is still fully charged, however, and remains so, since D_1 is reverse biased under this condition; C_2 is also fully charged, but, since its R_1-D_1 side has been pulled down to ground volts, it drives Q_3 base sharply negative, so Q_3 is cut off; C_3 thus has no discharge path at this stage, and therefore retains full charge. Consequently, should the points bounce open again at this stage (point bounce only occurs within the first two or three hundred microseconds of initial point closure), the s.c.r. will not be triggered back on again. Now, as soon as the points close, the C_2 charge starts to leak away via R_2, and eventually, after about 600 μs, the charge falls to near-zero and Q_3 is biased on via R_2 and R_{13}; once it is biased on, Q_3 provides a discharge path for C_3 via its collector and R_3 and R_4; C_3 then discharges rapidly, with a time constant of about 35 μs. At the end of this period, C_2 and C_3 are once more fully discharged, and the s.c.r. is ready to be triggered on again as soon as the C.B. points open once more.

Thus, the s.c.r. is triggered on as soon as the points open, but cannot be operated again until the points open once more after being fully closed for at least 600 μs. The s.c.r. is thus immune to false triggering by C.B. point bounce.

The +ve ground version of the C–D ignition system is shown in Fig. 1.6. This is similar to that described above, except that a few circuit polarities are changed, that Q_3 is a pnp rather than an npn transistor, and that the s.c.r. is triggered on with a –ve pulse applied to its cathode via D_2.

Construction and use

The only problem involved in the construction of the unit is that of finding transformer T_1. This is an iron-cored unit with a basic turns ratio of 15:1 at a power rating of 30 VA or greater, and with a centre-tapped low voltage winding. The easiest way to obtain this unit is to

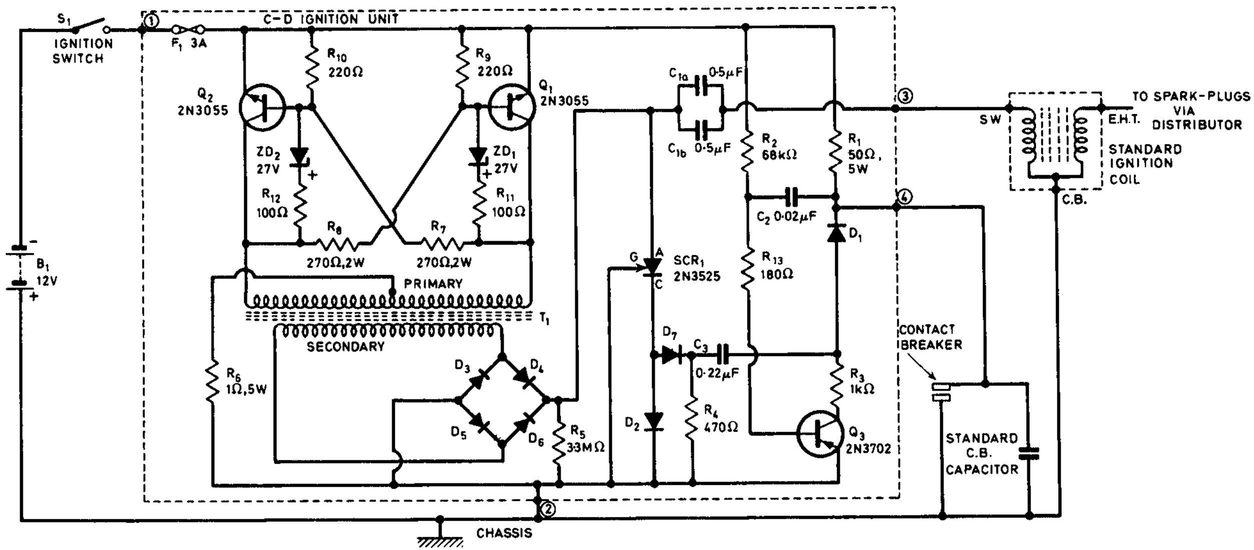


Fig. 1.6. Circuit and connections of the +ve ground version of the unit

rewind an existing l.t or battery-charger transformer. The winding procedure is very simple, and the following is an account of that used on the prototype.

The transformer is required, before modification, to have a basic turns ratio of 15:1 or less. Any l.t or battery charger transformer that meets this and the 30 VA power requirement can thus be used. The prototype unit started life as a 240 V:17 V, 2 A battery charger transformer, and thus satisfied the above specification; once selected, the low voltage winding of the unit must be rewound and centre-tapped to give an exact 15:1 ratio, i.e., a ratio of 240 V:16 V in this particular case.

To rewind the transformer, remove the securing clamp and dismantle the iron-core laminations (making note of their method of assembly), and then remove the coil bobbin. Next, unwind the entire low-voltage winding (which is invariably the outer winding on the bobbin), and carefully note the total number of turns used; now divide the number of turns by the original value of l.t voltage, to give the basic turns-per-volt value. On the prototype, total turns were 134, and the original voltage was 17, giving a turns-per-volt value of 7.9. Now calculate the l.t voltage needed to satisfy the 15:1 final turns ratio of the transformer (16 V in this case) and multiply by the turns-per-volt value (7.9) to give the total number of turns to be rewound (128); now rewind this number of turns on the bobbin, taking care to make a tap at the half-way mark. Finally, re-assemble the core laminations and re-fit the transformer clamp; the transformer is then complete and ready for use.

Construction of the rest of the unit should present no problems, and it can be wired up directly from the circuit diagram. The prototype +ve ground version of the unit (see Plate 1.1) is mounted in an 8 x 6 x 2½ in aluminium box; the two power transistors (Q_1 and Q_2) and the s.c.r. are mounted, via insulating washers, to the box surface (which acts as a heat sink); most of the remaining components are mounted on a piece of Veroboard panel; external connections to the unit are made via a 4-way terminal block.

When construction is complete, give the unit a simple functional check by connecting terminal 2 to chassis and terminal 1 to the 'hot' side of the car battery; a 'humming' noise should now come from the unit, indicating that the converter section is operating, and total current consumption should be roughly 800 mA; approximately 400 V should be available between the anode and cathode of the s.c.r. when tested with a 20,000 Ω/V meter. If this test is satisfactory, the unit can now be installed in the vehicle.

The complete unit can be either mounted in the glove compartment (as in the case of the prototype), or can be fixed to the rear fire-wall of the engine compartment (but not close to the exhaust system). The unit can be either wired directly to the existing coil and C.B. assembly,

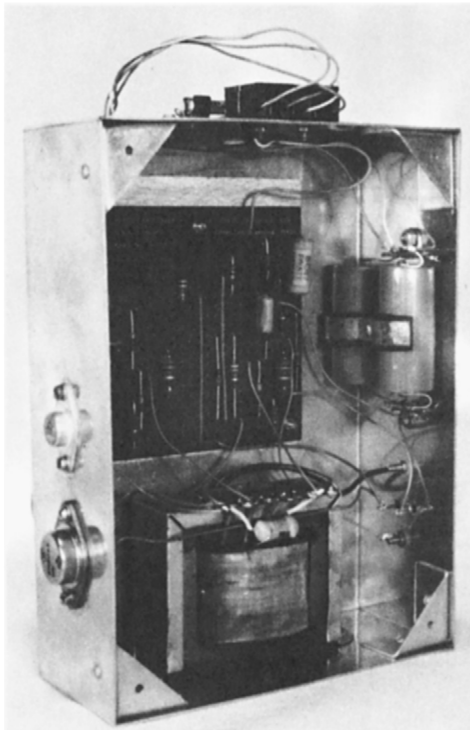


Plate 1.1

or, preferably, can be wired to these components via a 5-way plug and socket, in which case the driver can change from conventional to C–D ignition by simply fitting an alternative plug into the socket. If the unit is to be wired up directly, proceed as follows.

Wire the 2 terminal of the unit to chassis; remove the ignition switch wire from the coil and connect it to terminal 1 of the unit; connect terminal 3 to the coil terminal vacated by the ignition lead; disconnect the contact-breaker lead from the coil, and connect it to terminal 4 of the unit; connect the vacated C.B. terminal of the coil to ground. The connections are now complete.

If the unit is to be connected up via a 5-way plug and socket, wire up the socket as shown in Fig. 1.7a, and wire up two plugs as shown in Figs. 1.7b and c; when wiring is complete, fix the C–D plug in the socket.

Once wiring is complete, turn on the ignition, operate the starter, and check that the system functions well under actual driving conditions; there is no need to re-adjust C.B. or spark-plug gaps, etc.

The most noticeable improvement in performance obtained on the

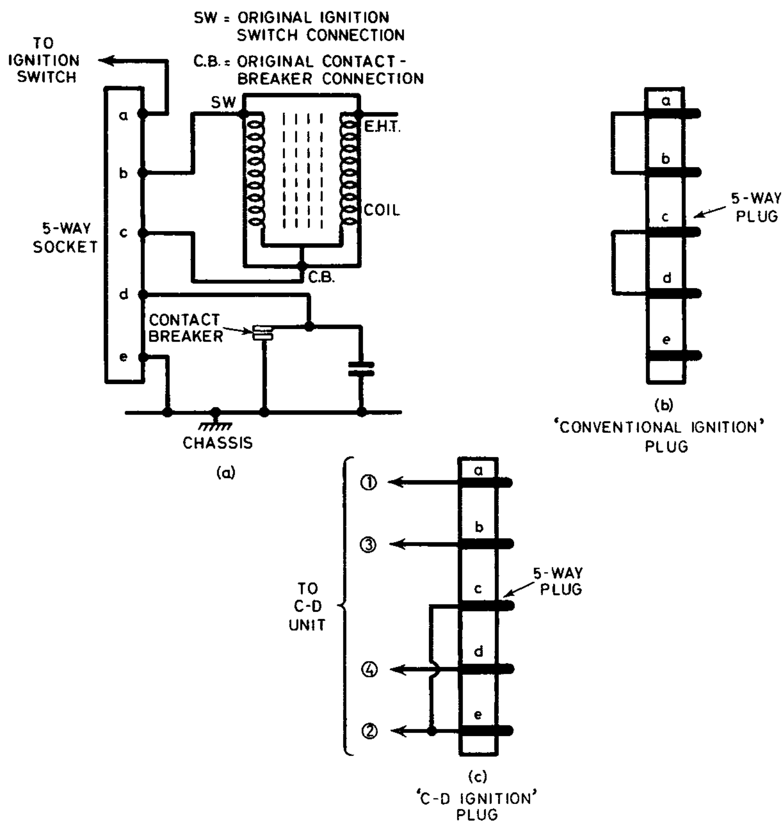


Fig. 1.7. Plug and socket connections for wiring the unit to the vehicle

prototype system is easier starting and better top speed performance; acceleration is also better, and fuel economy is improved by 2 to 5%. Results vary from one car to another, but improvements are particularly evident in cars that have covered a considerable mileage since their last tune-up.

Finally, once the unit has been found to perform satisfactorily over a reasonable mileage, it is recommended that the entire circuit be covered with an electrically insulating coat of waterproof paint or varnish, to exclude the harmful effects of moisture. The unit can then be expected to operate correctly throughout the life of the vehicle.

Project 2

AUTOMATIC PARKING LIGHT OPERATOR

This simple little unit turns a car's parking or side lights *on* automatically when it gets dark in the evening, and turns them *off* again when it gets light in the morning. The light triggering levels can be pre-set to suit individual requirements, and are independent of actual battery voltage. The circuit responds to *mean* light levels only, and is unaffected by sudden changes in light level, such as are caused by lightning flashes or passing shadows, etc.

The major part of the circuit is wired up on a 2½ x 1⅛ in piece of Veroboard panel, and the entire unit can be built and installed in the vehicle in a single evening. The device can be used in any vehicle fitted with a 12 V (+ve or –ve ground) lighting system.

How it works

The full circuit of the automatic parking light operator is shown in Fig. 2.1. Circuit operation is very simple. R_1 and zener diode ZD_1 act as a simple voltage stabilizer, and apply a fixed potential of 6 V to the top of R_2, irrespective of actual battery voltage. *LDR* is a cadmium sulphide photocell, and acts as a low resistance under bright conditions and as a high resistance under dark conditions; R_2 and the *LDR* act together as a simple potential divider network, so the voltage at the R_2–*LDR* junction varies in proportion to the light level on the face of the *LDR*. This voltage is smoothed by R_3 and C_1 and is passed on, via

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Project 2

AUTOMATIC PARKING LIGHT OPERATOR

This simple little unit turns a car's parking or side lights *on* automatically when it gets dark in the evening, and turns them *off* again when it gets light in the morning. The light triggering levels can be pre-set to suit individual requirements, and are independent of actual battery voltage. The circuit responds to *mean* light levels only, and is unaffected by sudden changes in light level, such as are caused by lightning flashes or passing shadows, etc.

The major part of the circuit is wired up on a 2½ x 1⅛ in piece of Veroboard panel, and the entire unit can be built and installed in the vehicle in a single evening. The device can be used in any vehicle fitted with a 12 V (+ve or –ve ground) lighting system.

How it works

The full circuit of the automatic parking light operator is shown in Fig. 2.1. Circuit operation is very simple. R_1 and zener diode ZD_1 act as a simple voltage stabilizer, and apply a fixed potential of 6 V to the top of R_2, irrespective of actual battery voltage. *LDR* is a cadmium sulphide photocell, and acts as a low resistance under bright conditions and as a high resistance under dark conditions; R_2 and the *LDR* act together as a simple potential divider network, so the voltage at the R_2–*LDR* junction varies in proportion to the light level on the face of the *LDR*. This voltage is smoothed by R_3 and C_1 and is passed on, via

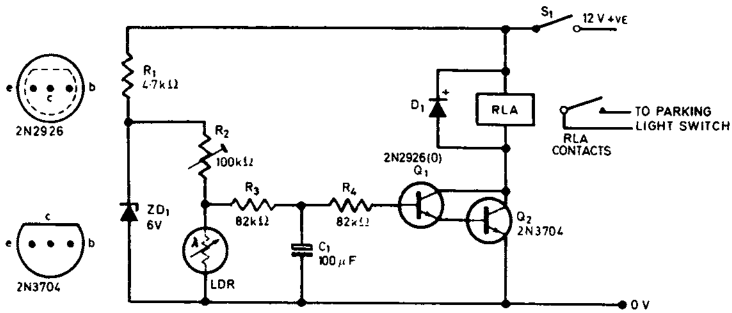


Fig. 2.1. Circuit of the automatic parking light operator

Components list (Fig. 2.1)

R_1	=	4.7 kΩ,	¼ W
R_2	=	100 kΩ,	skeleton pre-set vertical mounting
R_3	=	82 kΩ,	¼ W
R_4	=	82 kΩ,	¼ W
C_1	=	100 μF,	6 V electrolytic
LDR	=	Cadmium sulphide photocell, ¼ to ½ in face diameter, resistance = approx 2 kΩ to 5 kΩ at 100 lux i.e., type TPMD–6LS by Sanken (Japan) or similar	
ZD_1	=	zener diode, 6 V, 300 mW	
Q_1	=	2N2926, orange coded (G.E.)	
Q_2	=	2N3704 (Texas)	
RLA	=	12 V relay, 120 Ω or greater coil resistance, one N/O contact with current rating to suit parking lights.	
S_1	=	On/off switch	
		Veroboard, hook-up wire, etc.	

R_4, as base-bias to Q_1. Q_1 and Q_2 are wired as a super-alpha pair, and act like a single transistor with a very high current gain; this 'transistor' is wired in the common emitter mode, with relay *RLA* as its collector load, and is driven *on* only when its base bias exceeds 1.2 V.

Thus, under bright conditions only a very low voltage appears at the R_2–*LDR* junction, so negligible voltage is fed to Q_1 base; Q_1–Q_2 and the relay are therefore *off*. Under dark conditions, on the other hand, a large voltage is developed at the R_2–*LDR* junction, so heavy base bias is applied to Q_1, and Q_1–Q_2 and the relay are driven *on*. The car's parking or side lights are activated by the relay's switching contacts, and are *off* when the relay is *off*, and are turned *on* when the relay is *on*.

Since the voltage at the top of the R_2–*LDR* potential divider network is stabilized at 6 V, the voltage at the actual R_2–*LDR* junction is dictated purely by the R_2 and *LDR* values, and is unaffected by

variations in actual battery voltage. The light trigger levels of the circuit can thus be pre-set via R_2, and are unaffected by battery voltage variations. The smoothing action of the R_3-C_1 network ensures that Q_1 base-bias voltage corresponds to *mean* values of R_2-LDR junction voltage, determined over a period of several seconds. The switching action of the circuit is thus unaffected by sudden variations in light level, such as those caused by lightning flashes and passing shadows, etc. C_1 must be temporarily disconnected from the circuit when pre-setting the unit's trigger levels.

Construction and use

The major part of the circuit, less the relay and *LDR*, is wired up on a 2½ x 1⅛ in piece of Veroboard with 0.15 in hole spacing, and Figs. 2.2a and 2.2b show constructional details on this panel. A photograph of the completed panel is shown in Plate 2.1. When the panel is complete it can be mounted, together with the relay, in a suitable case; if a metal

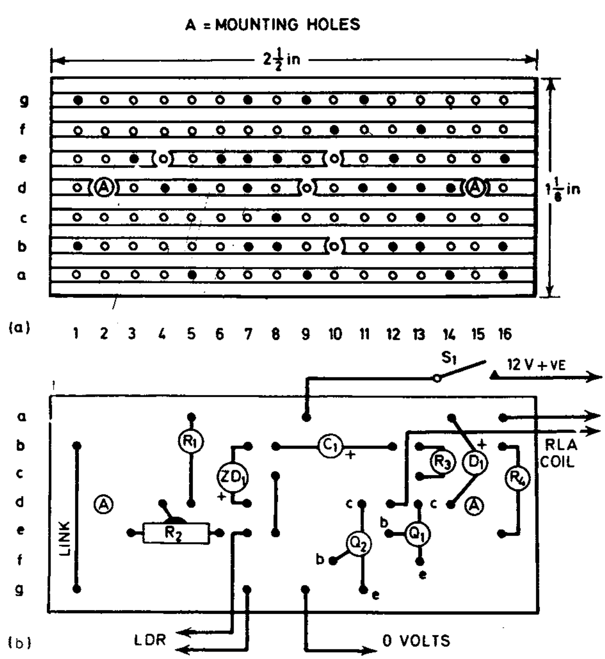


Fig. 2.2. Veroboard arrangement
(a) Copper side
(b) Component assembly on plain side

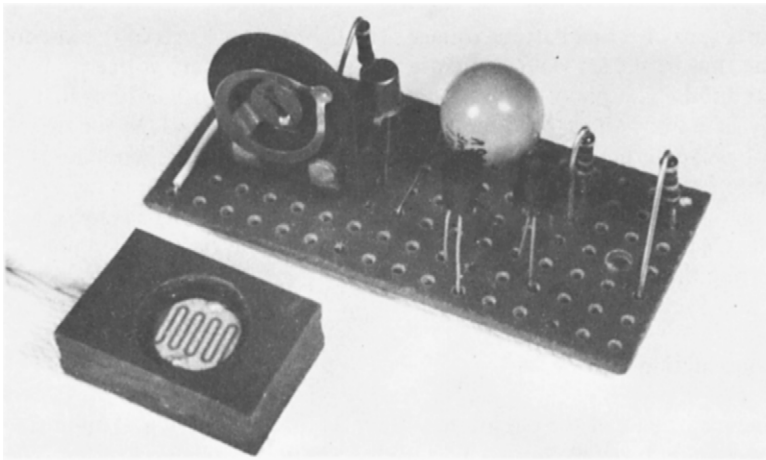


Plate 2.1

case is used, bond a couple of small rubber grommets to the underside of the panel, one below each mounting hole, to act as spacer/insulators to prevent the copper strips shorting to the case.

The relay can be any 12 V type with a coil resistance greater than 120 Ω, and with one or more normally open (N/O) contacts with a current rating suitable for operating the car's lights. A 700 Ω relay with a 5 A contact was used on the prototype unit.

The *LDR* must be mounted in a small 'head' and connected to the circuit via a pair of flexible leads. The head itself must be bonded (with impact adhesive or sticky tape) to a suitable surface inside the car, with the *LDR* face looking into the interior of the vehicle; this method of mounting enables the *LDR* to see mean light levels, but to be almost blind to localized external lighting such as headlamps and street lights, etc. Suitable mounting positions are the lower face of the windshield, the front of the dash panel, or the head of the steering column support bracket.

The *LDR* head is made by connecting a pair of flexible leads to the *LDR* and sinking the assembly into a block of plastic so that only the *LDR* face is exposed; the object of this process is to exclude light from all but the face of the *LDR*, while at the same time providing the *LDR* with flexible connections and a flat rear surface that can be readily bonded to the car. Fig. 2.3 shows how the prototype head was made.

Here, the *LDR* leads are first cut off short and their stumps are soldered to lengths of hearing aid or similar flex; the wire stumps are then bent over at right angles to the *LDR*. The *LDR* assembly is then bonded between a sandwich of plastic or wood. The upper half of the sandwich has a hole cut in it, to clear the *LDR* body, and the lower half

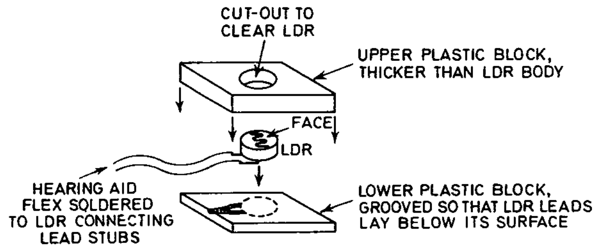


Fig. 2.3. Method used for making prototype LDR head

is grooved so that the *LDR* leads can lay below its surface; when the two halves are bonded together they and the *LDR* form a solid block in which only the *LDR* face and leads are exposed. The head is then complete.

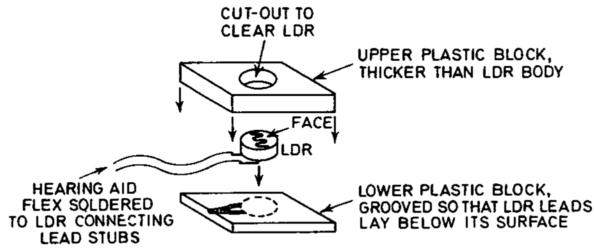
When assembly of the electronic circuitry and the head is complete, the unit can be installed and adjusted as follows.

Bond the *LDR* head in position in the vehicle, and connect it to the main circuit via its flexible leads; temporarily disconnect one side of C_1. Connect the unit's 12 V +ve lead to the +ve terminal of the vehicle's battery, and the 0 V lead to the –ve terminal. Wire the relay contacts across the parking light switch. Now close S_1, reduce the effective ambient light level to the required value (by shading the *LDR* face or waiting for dusk), and adjust R_2 so that the parking lights come on; now increase the light level, and check that the lamps go off again. Now re-connect C_1, and check that the parking lights still operate, after a period of a few seconds, at the required lighting levels, but are unaffected by sudden variations in light level. If satisfactory, the unit is now complete and ready for use.

Project 3

WINDSHIELD WIPER PAUSE CONTROLLER (1)

Conventional windshield wipers are designed to keep the screen clear in heavy rain, and under such conditions they do a good job. Under conditions of light rain or mist, however, their performance is rather poor; their first few sweeps wipe the screen clear, and all following sweeps are made against a near-dry surface and cause excessive wear of



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both the wiper unit and the screen. Performance is even worse when driving on wet roads after a shower; in these conditions leading traffic throws a wet mist of dirt over the windshield, and continuously operating wipers simply smear this dirt across the screen and grind away the surface polish.

The unit described here overcomes these deficiencies of performance. It causes the wipers to sweep back and forth at normal speed, but to pause automatically in the parked position for a pre-set period between individual sweeps, thus giving a wipe-pause-wipe action. The pause periods give time for moisture to build up and lubricate the screen between sweeps, thus preventing smearing, and can be varied from less than one second (for operating in fairly heavy rain) to about twenty seconds (for keeping the screen clear of traffic spray on wet roads). The unit can be bypassed by the normal wiper control switch for operation in heavy rain.

The unit is compact (the prototype measures a mere 3¾ x 1⅜ x 1¼ in), fairly inexpensive, and easy to make and instal. It can be fitted to about 65% of existing vehicles, i.e., most vehicles fitted with normal electrically operated 12 V (+ve or –ve ground) self-parking windshield wipers. The unit can NOT be used on cars fitted with 6 V systems, with non-electric wipers, or with non-self-parking wipers. Nor can it be used on some current production vehicles fitted with permanent magnet wiper motors having dynamic braking facilities; a controller suitable for operating this last mentioned type of wiper is described in Project 4.

How it works

To appreciate just how the pause controller works we must first understand the operating principle of a normal self-parking wiper unit. With this in mind, Fig. 3.1 shows the circuit of a conventional self-parking wiper assembly (within the dotted box) and its control switch (S_2).

A self-parking switch (S_1) is built into the motor assembly and is activated by a cam that is mechanically coupled to the electric motor; this switch is wired between one side of the motor and ground, and is open when the wipers are parked, but closed when the wipers are sweeping. *On/off* switch S_2 is wired in parallel with S_1.

Thus, when S_2 is closed the motor is connected directly across the 12 V supply and the wipers operate; once the motor starts into its sweep S_1 is closed via the cam, so the motor then continues to operate independently of S_2, until eventually the motor returns to the self-park position and S_1 opens again; if S_2 is open at this moment, the motor stops in the self-park position, but if S_2 is closed S_1 is effectively shorted out and the wiper starts into its next sweep.

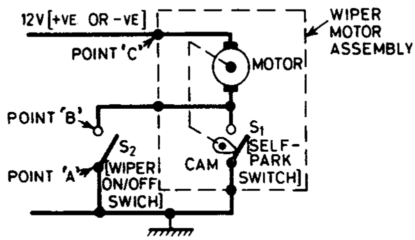

Fig. 3.1. Circuit of a conventional self-parking windshield wiper and its control switch

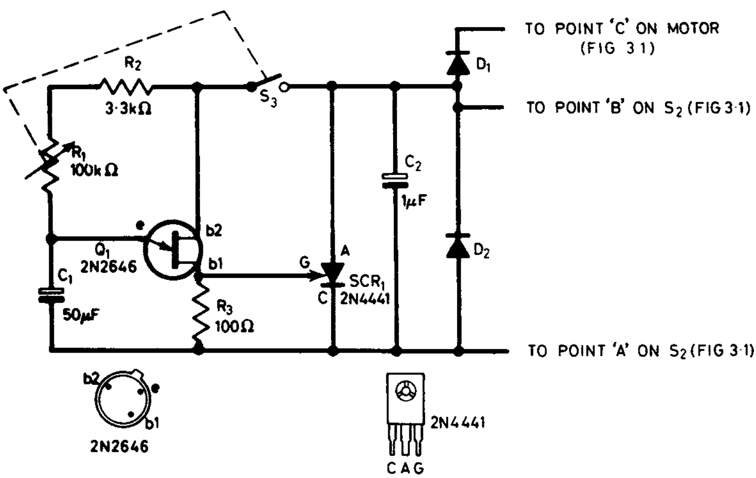

Fig. 3.2. Circuit, connections, and semiconductor details of –ve ground version of the wiper pause controller

Components (Figs. 3.2 and 3.3)

R_1 = 100 kΩ log, ganged to S_3
R_2 = 3.3 kΩ, ¼ W
R_3 = 100 Ω, ½ W
C_1 = 50 μF, 12 V electrolytic
C_2 = 1 μF, 18 V electrolytic
S_3 = on/off switch, ganged to R_1
Q_1 = 2N2646 unijunction (G.E.)
SCR_1 = 2N4441 s.c.r. (Motorola)
D_1, D_2 = 1N4001 or similar (Motorola, Texas, etc.)
Veroboard, hook-up wire, etc.

Normal running currents of the motor are typically about 3 A, but switch-on surge currents may reach 24 A. When the motor switches off as S_1 opens, the collapsing magnetic field of the motor causes a heavy back-e.m.f (typically of about 200 V peak) to be applied across S_1 and S_2. Having cleared up these details we can now go on to look at the actual pause control circuit.

Fig. 3.2 shows the practical circuit and connections of a pause controller for 12 V negative ground systems. Silicon controlled-rectifier $S.C.R_1$ is wired in parallel with S_2, and Q_1 is a unijunction transistor wired as a simple timer circuit. Circuit operation is very simple. Assume that S_2 is open; when S_3 is closed, voltage is applied to Q_1 via the wiper motor, and C_1 starts to charge exponentially via R_1 and R_2; after a delay determined by the setting of R_1, the C_1 voltage reaches the firing potential of Q_1, and the u.j.t. fires and discharges C_1 into the gate of the s.c.r., thus triggering the s.c.r. on. Once the s.c.r. is triggered on it self-latches and acts like a closed switch, so power is applied to the motor and the wipers start to move. As the wipers move into the sweep, self-park switch S_1 closes, and so shorts out the s.c.r. and Q_1 circuit, which thus turn off and re-set, and the motor completes the sweep via S_1. At the end of the sweep S_1 again opens, so Q_1 starts into another timing cycle, at the end of which it again fires the s.c.r. and re-starts the wipers. This process continues so long as S_3 is closed. When S_3 is opened, power is no longer applied to the Q_1 circuit at the end of each sweep, so circuit operation ceases.

R_1 enables the timing delay periods of the circuit to be varied from less than one second up to about 20 seconds. D_1 and D_2 limit the switch-off back-e.m.f of the motor to about 13 V positive, thus eliminating the danger of possible semiconductor damage at the moment of switch off, and C_2 limits the rate-of-rise of $S.C.R_1$ anode voltage, thus ensuring that the s.c.r. is not turned on by switching transients.

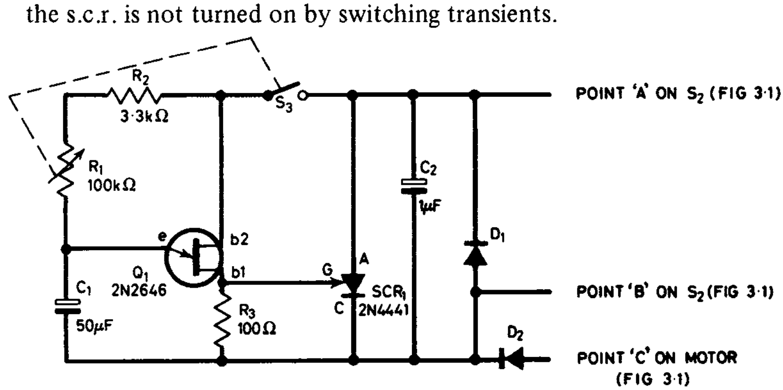

Fig. 3.3. Circuit and connections of +ve ground version of the pause controller

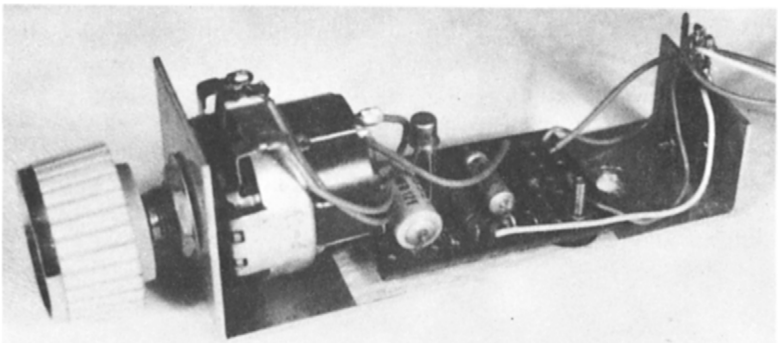

Plate 3.1

The positive ground version of the unit, shown in Fig. 3.3, is almost identical to that described above, except that the circuit connections are changed. In both circuits the specified s.c.r.s have maximum forward current ratings of 8 A average and 80 A surge, and thus have ample safety margins for operating the wiper motors. D_1 and D_2 have surge ratings in excess of 25 A, and can thus safely handle the switch-off currents of the motor.

Construction and use

Before starting construction, make sure that the wipers are suitable for operation by the pause controller circuit. This can be determined very simply, as follows. Gain easy access to the vehicle's wiper control switch terminals via a couple of clip-on wires; switch on the ignition, and touch-connect a 5 A to 8 A SLOW BLOW fuse across the switch terminals; the wipers should operate in the normal way. Let the wipers work through two or three sweeps, then remove the fuse half way through a following sweep; the wipers should continue through this sweep and then stop in the self-park position. If the wipers work as described above, the electronic unit can be safely used on the vehicle. If, on the other hand, the fuse blows during these tests, or the wipers fail to self-park, the unit cannot be used on the vehicle.

Assembly details of the pause controller are in no way critical, and can be varied to suit individual needs. The s.c.r. should, however, be mounted on a small heat sink to prevent overheating. Plate 3.1 shows one method of construction, where the s.c.r. can be seen mounted on the base-plate at the right. The completed unit can be fixed under the car's dash panel, and the three external leads can be wired up to the

existing wiper switch and motor directly or via a 3-way terminal block.

Once the unit is installed, carry out a functional test as follows. Turn on the vehicle's ignition, close S_3, and check that the wipers start operating after a short delay. They should make a single sweep, then pause, then make another sweep, and so on, pausing in the self-park position at the end of each sweep. It should be possible to vary the delay periods up to about 20 seconds via R_1. Longer periods can be obtained, if required, by increasing the value of C_1. The unit is now complete and ready for use.

Project 4

WINDSHIELD WIPER PAUSE CONTROLLER (2)

This unit performs the same function as that described in Project 3, but is specifically intended for use in modern vehicles fitted with permanent magnet wiper motors having dynamic braking facilities.

How it works

Fig. 4.1a shows the circuit of a self-parking permanent magnet wiper unit with dynamic braking facilities. S_1 is a self-park switch that is built into the motor assembly and is activated by a cam that is mechanically coupled to the motor. S_2 is the master *on/off* switch.

When S_2 is moved to the *on* position, the motor is connected across the 12 V supply line and S_1 is effectively cut out of the circuit, so the motor operates continuously and the wipers sweep back and forth. Suppose, however, that the wipers are part way through a sweep when S_2 is turned to the *off* position; in this case S_1 is connected back in circuit and keeps the motor connected across the supply until the cam reaches the self-park position; when the cam reaches the self-park position S_1 changes over; in doing so it simultaneously breaks the motor supply and connects a short circuit across the motor armature; a dynamic braking effect thus takes place, and the motor stops abruptly in the self-park position.

Fig. 4.1b shows, in simplified form, how the circuit can be modified for operation via a pause controller unit. In this case change-over relay contacts *RLA/1* are wired between points 'b' and 'c' of the original circuit, and the relay is operated by a variable time-delay circuit that is

existing wiper switch and motor directly or via a 3-way terminal block.

Once the unit is installed, carry out a functional test as follows. Turn on the vehicle's ignition, close S_3, and check that the wipers start operating after a short delay. They should make a single sweep, then pause, then make another sweep, and so on, pausing in the self-park position at the end of each sweep. It should be possible to vary the delay periods up to about 20 seconds via R_1. Longer periods can be obtained, if required, by increasing the value of C_1. The unit is now complete and ready for use.

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connected to point 'c' via S_3. When S_3 is open, the relay circuit is inoperative, and points 'b' and 'c' are shorted together via *RLA/1*, so the wiper unit functions in the normal way.

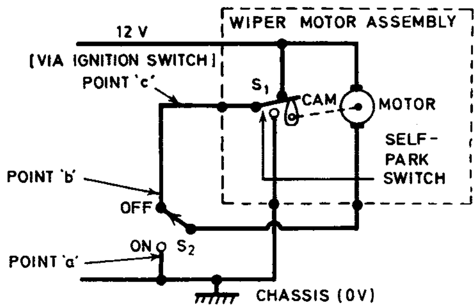

Fig. 4.1a. Circuit of self-parking permanent magnet wiper unit with dynamic braking facilities

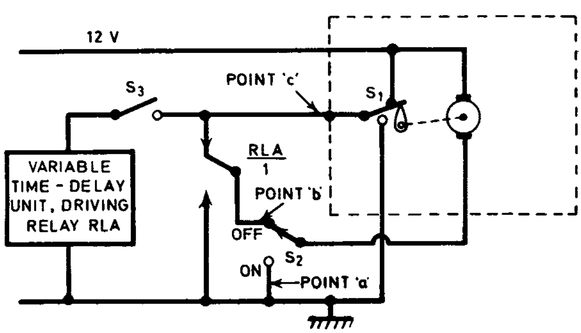

Fig. 4.1b. Modification of basic circuit for operation via a pause controller

Suppose, on the other hand, that S_2 is in the *off* position, and S_3 is closed. As soon as S_3 is closed the time-delay unit starts a timing cycle, and after a pre-set period it turns relay *RLA* on. As *RLA* goes on, contact *RLA/1* changes over, and connects the motor across the supply. The motor thus starts into a sweep; shortly after the start of the sweep, cam-operated switch S_1 shorts point 'c' to ground, and thus removes the supply to the relay driving circuit; the relay thus turns off, and contact *RLA/1* returns to its original position, shorting points 'b' and 'c' together; since point 'c' is shorted to ground via S_1 at this time, the motor continues to operate until it returns to the self-park position, at which point it brakes dynamically in the normal way as S_1 changes over.

As S_1 changes over, the supply is reconnected to the time-delay unit via S_3, and another timing cycle starts, at the end of which the relay again goes momentarily on, and the process repeats.

Fig. 4.2 shows the practical circuit of a negative ground relay-driving time delay unit, or pause controller. The positive ground version is identical, except that the connections to points 'X' and 'Y' are reversed. The circuit is basically similar to that of Fig. 3.2. Q_1 is a unijunction transistor, wired as a simple timer circuit, and $S.C.R_1$ is a silicon controlled-rectifier, but in this case the s.c.r. has relay *RLA* connected as its anode load.

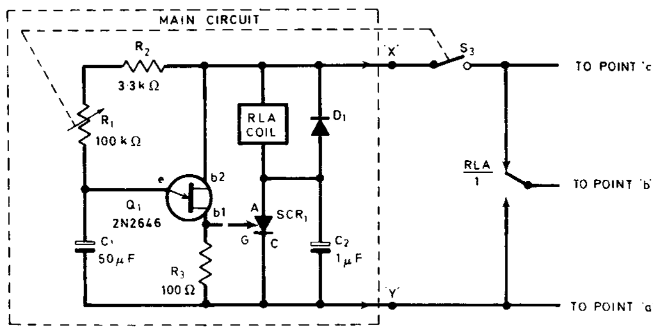

Fig. 4.2. Pause controller, –ve ground version. For +ve ground version, reverse connections of main circuit to points x and y

Components list (Fig. 4.2)

R_1	=	100	kΩ log, ganged to S_3		
R_2	=	3.3	kΩ,	¼ W	
R_3	=	100	Ω,	½ W	
C_1	=	50	µF,	12 V	electrolytic
C_2	=	1	µF,	18 V	electrolytic
RLA	=	12 V relay, 22 Ω to 680 Ω coil resistance			
S_3	=	on/off switch, ganged to R_1			
Q_1	=	2N2646 unijunction (G.E.)			
SCR_1	=	any 1 A s.c.r. with a p.i.v. rating or 25 or greater			
D_1	=	1N4001 or similar			

Operation of the circuit is very simple. When S_3 is closed, power is applied to the circuit and C_1 starts to charge via R_1 and R_2. After a predetermined period the C_1 voltage reaches the firing potential of Q_1, and Q_1 fires and turns the s.c.r. and tne relay on; once the s.c.r. is triggered on it self-latches, and thus stays on even though the trigger pulse may be removed. D_1 prevents any back-e.m.f from the relay coil damaging the semiconductor circuitry as the relay operates, and C_2 ensures that the s.c.r. is not triggered by transients in the supply line.

Construction and use

Construction of the unit is in no way critical, and can be varied to suit individual requirements. The s.c.r. can be any 1 A type with a voltage rating of 25 p.i.v or greater, and does not need to be mounted on a heat sink; the relay can be any 12 V type with a coil resistance in the range 22 to 680 Ω, and with one or more sets of change-over contacts rated at 2 A or greater. The completed unit can be mounted under the car's dash panel.

When construction is complete, give the unit a simple functional test before installing it in the vehicle: Connect the unit to a 12 V supply via S_3, and check that the relay goes on after a short delay; check that the delay can be varied from about 1 to 20 seconds via R_1; longer delays can be obtained by increasing the value of C_1, if required. Check that the s.c.r. self-latches and holds the relay on correctly; if it does not, shunt the relay coil with a fixed resistance to increase the *on* current of the s.c.r. Once these tests are satisfactory the unit can be installed in the vehicle to conform to Fig. 4.1b, the relay contacts being inserted between points 'b' and 'c', and the unit is then complete and ready for use.

To use the unit, turn on the ignition and operate S_3 and R_1; the wipers should, after a short delay, make one complete sweep, then pause, then make another sweep, and so on; the pause periods are variable using R_1.

Project 5

LIGHTS-ARE-ON REMINDER

The lights-are-on reminder automatically sounds an alarm if the car's lights are left on after the ignition is turned off, i.e., after the car is parked. Two basic versions of the unit are described here. The first uses a bell or buzzer as the alarm generator. The second version uses an electronic alarm generator.

Basic version of the unit

Fig. 5.1 shows the negative ground version of the basic lights-are-on reminder, using a 12 V buzzer or bell as the alarm generator. Operation

Construction and use

Construction of the unit is in no way critical, and can be varied to suit individual requirements. The s.c.r. can be any 1 A type with a voltage rating of 25 p.i.v or greater, and does not need to be mounted on a heat sink; the relay can be any 12 V type with a coil resistance in the range 22 to 680 Ω, and with one or more sets of change-over contacts rated at 2 A or greater. The completed unit can be mounted under the car's dash panel.

When construction is complete, give the unit a simple functional test before installing it in the vehicle: Connect the unit to a 12 V supply via S_3, and check that the relay goes on after a short delay; check that the delay can be varied from about 1 to 20 seconds via R_1; longer delays can be obtained by increasing the value of C_1, if required. Check that the s.c.r. self-latches and holds the relay on correctly; if it does not, shunt the relay coil with a fixed resistance to increase the *on* current of the s.c.r. Once these tests are satisfactory the unit can be installed in the vehicle to conform to Fig. 4.1b, the relay contacts being inserted between points 'b' and 'c', and the unit is then complete and ready for use.

To use the unit, turn on the ignition and operate S_3 and R_1; the wipers should, after a short delay, make one complete sweep, then pause, then make another sweep, and so on; the pause periods are variable using R_1.

Project 5

LIGHTS-ARE-ON REMINDER

The lights-are-on reminder automatically sounds an alarm if the car's lights are left on after the ignition is turned off, i.e., after the car is parked. Two basic versions of the unit are described here. The first uses a bell or buzzer as the alarm generator. The second version uses an electronic alarm generator.

Basic version of the unit

Fig. 5.1 shows the negative ground version of the basic lights-are-on reminder, using a 12 V buzzer or bell as the alarm generator. Operation

is very simple. Assume that S_1 is in the *Normal* position. If both the lights and ignition are on, points 'X' and 'Y' both appear at the same potential, so zero current flows through the alarm unit, which is thus off. Again, if both the lights and ignition are off, points 'X' and 'Y' are both held at ground potential (via LP_1 and R_1 respectively), so the alarm is again off. If, on the other hand, the ignition is on and the lights are off, point 'Y' will be at 12 V +ve and point 'X' will be at ground potential; D_1 is thus reverse biased under this condition, so the alarm is once more off.

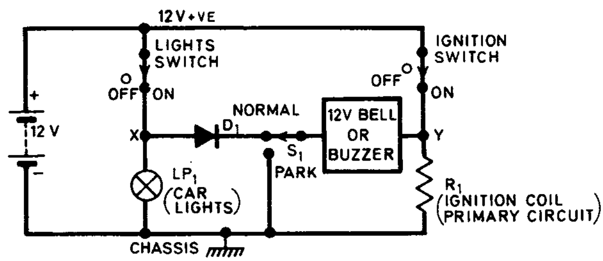

Fig. 5.1. Basic lights-are-on reminder (negative ground version)

Finally, suppose that the ignition is off and the lights are on. Under this condition 12 V +ve appears at point 'X', and point 'Y' is held at ground potential via R_1 ; D_1 is thus forward biased under this condition, so the alarm operates, indicating that the lights have been left on after the car is parked. Should the owner decide to keep the parking lights on for the night, S_1 must be moved to the *Park* position to stop the alarm operating: When the ignition is then turned on again in the morning, the alarm will instantly operate, warning the driver to switch S_1 back to the *Normal* position.

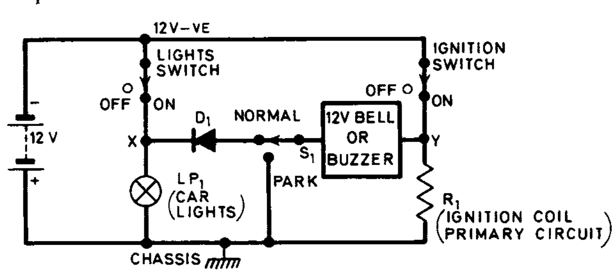

Fig. 5.2. Basic lights-are-on reminder (positive ground version)

The positive ground version of the unit, shown in Fig. 5.2, is identical to that described above, except that the polarities of D_1 and the supply leads are reversed. In both versions of the unit, D_1 can be any silicon rectifier having a current rating greater than that of the alarm unit.

Electronic version of the unit

When the car lights are left on using the electronic version of the unit, a loud and fairly high frequency 'reminder' tone is generated as soon as the ignition is turned off; if the lights are left on (for night parking) the volume and frequency of the alarm then decay down to zero over a period of about 15 seconds. The alarm thus turns itself off automatically after a limited time, and consequently eliminates the need for the manually operated switch (S_1) of the previous units.

The full circuit of the electronic unit is shown in Fig. 5.3. D_1 serves the same function as the diode used in the earlier units, and the remainder of the circuit acts as the alarm generator. The generator is a modification of the complementary astable multivibrator, and uses an 8 Ω speaker as part of its Q_2 collector load. The circuit only operates when it is connected to supplies of the polarities shown, and these connections occur only when the car's light switch is left on with the ignition turned off.

When connected to supplies of the polarities shown, the operating frequency and the volume of the unit is determined by the values of R_3–R_4 and C_1, and by the voltage at the junction of R_3 and C_2. When the R_3–C_2 junction is at zero volts, the volume and frequency are high; the volume and frequency decrease as the R_3–C_2 junction is made more positive, and fall to zero as the junction voltage nears the +ve supply potential.

Now, in Fig. 5.3, R_3 and the base-emitter junction of Q_1 are wired in series with C_2, and act as a simple C_2-charging network. When the supplies are initially connected to the circuit (via the ignition and light switches), therefore, C_2 is fully discharged, so the R_3–C_2 junction is at zero volts, and the unit operates initially at high frequency and volume. C_2 then starts to charge via R_3 and the base-emitter junction of Q_1, and as it does so the R_3–C_2 junction voltage rises exponentially towards the +ve rail voltage, and causes the volume and frequency to decrease. Eventually, after about 15 seconds, R_3–C_2 junction voltage reaches such a value that oscillation ceases, and the unit turns off. The circuit then passes a total current of only 1 mA, via R_6. When the supply is removed from the circuit (by operating the lights or ignition switches), C_2 discharges rapidly via D_2 and R_6, and the unit is then ready to operate again as a lights-are-on reminder.

Construction and use

The electronic version of the unit is wired up on a 2½ x 1⅛ in piece of

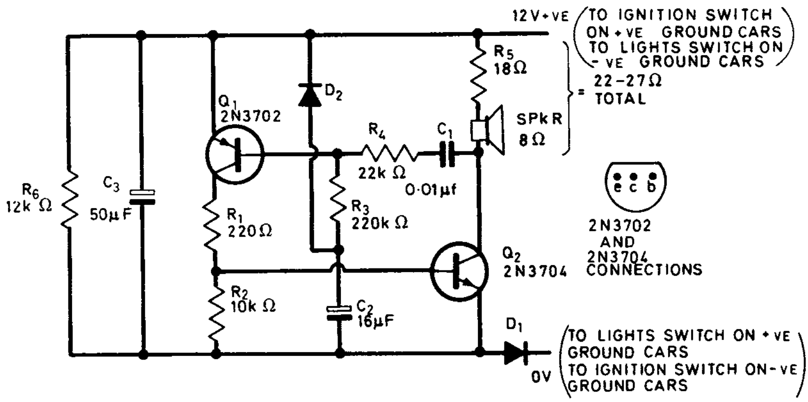

Fig. 5.3. Circuit and transistor connections of electronic version of the unit

Components list (Fig. 5.3)

R_1	=	220 Ω,	¼ W	
R_2	=	10 kΩ,	¼ W	
R_3	=	220 kΩ,	¼ W	
R_4	=	22 kΩ,	¼ W	
R_5	=	18 Ω,	¼ W	
R_6	=	12 kΩ,	¼ W	
C_1	=	0.01 μF,	Mylar	
C_2	=	16 μF,	15 V	electrolytic
C_3	=	50 μF,	15 V	electrolytic
Q_1	=	2N3702	(Texas)	
Q_2	=	2N3704	(Texas)	
D_1	=	200 mA or greater silicon diode (1N4001, etc.)		
D_2	=	general purpose silicon diode		
Spkr	=	miniature 8 Ω speaker		
		Veroboard, hook-up wire, etc.		

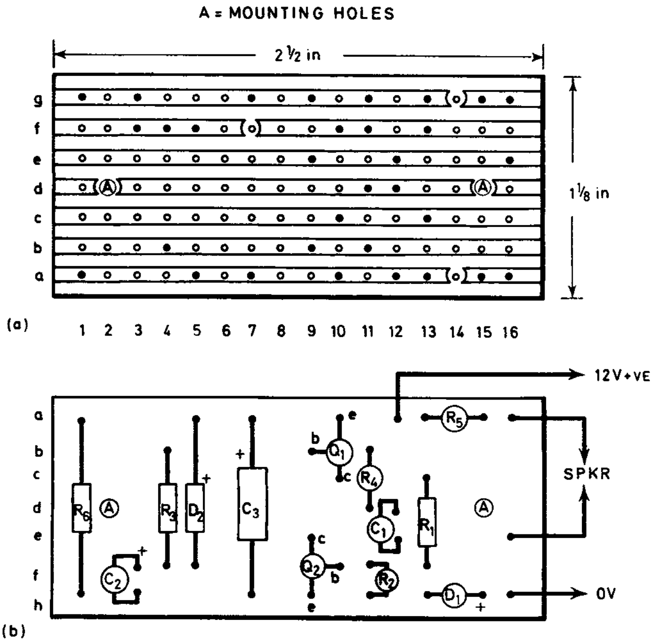

Fig. 5.4. Veroboard arrangement
(a) Copper side
(b) Component assembly on plain side

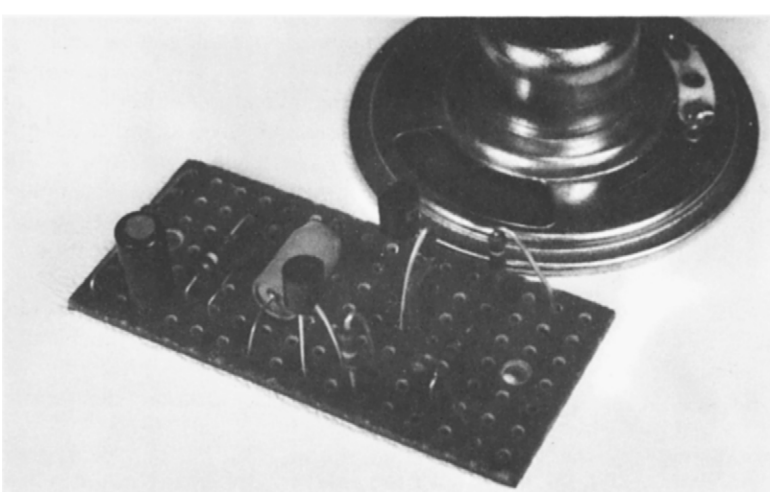

Plate 5.1

Veroboard with 0.15 in hole spacing, and Fig. 5.4 shows constructional details of this panel.

When the panel is complete, wire it up to the 8 Ω speaker and the car's ignition and lighting switches, to conform to Fig. 5.3. A photograph of the unit is shown in Plate 5.1. Now, with the ignition switch off, turn the car's lights on. The reminder alarm should operate briefly, starting at a fairly high frequency and then decaying down to zero over a period of about 15 seconds. The decay period can be increased, if required, by increasing the value of C_2; if extra volume is needed, use a higher impedance speaker and decrease the value of R_5 so that the total collector load of Q_2 is between 22 and 27 Ω.

Now try various combinations of light and ignition switch modes, i.e., lights and ignition on, lights and ignition off, lights off and ignition on, etc., and check that the unit only operates if the lights are on and the ignition is off. The unit is then complete and ready for use, and can be permanently installed in the vehicle.

Project 6

MULTI-INPUT PANEL LIGHT FLASHER

In following sections of this volume a number of fault and danger indicating projects are described. These include an ice-warning alarm, a lighting fault indicator, a low-fuel warning indicator, an overheat alarm, and a number of other units. Each of these units gives an indication of a fault or of danger by illuminating a low-power panel lamp. A snag with this system is that if the driver is concentrating on the road he is unlikely to notice the fault indication until some considerable time after it occurs. The reasons for this are three-fold. First, the fault indication is purely visual, and is out of the driver's normal focus of sight under actual driving conditions. Secondly, the illumination of each lamp is of relatively low intensity, and may be masked by bright sunlight. Finally, and most important of all, each fault light burns steadily once illuminated, and the attention of the human brain is simply not greatly attracted by steady phenomena.

The unit described here overcomes the snags outlined above. It does so by flashing a fairly high-intensity master panel light on and off when one or more of the low-intensity fault lamps is illuminated, and at the same time emits a series of audible clicks. Thus, when a fault occurs the driver's attention is immediately attracted by the flashing and clicking

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of the master lamp circuit, and he can then look at the bank of fault lamps to locate the precise cause of the trouble, i.e., overheat, ice warning, low fuel, etc.

How it works

The full circuit of the negative ground version of the multi-input panel light flasher is shown in Fig. 6.1. Circuit operation is quite simple. Assume initially that a short is wired between Q_4 collector and the 0 V line. In this case Q_1 and Q_2 operate as a normal astable multivibrator, with Q_2 collector switching alternatively between 0 V and 12 V +ve, at a rate of about 80 cycles per minute. Q_2 collector is coupled to Q_3 base via R_5, and Q_3 is wired as a common emitter amplifier with relay *RLA* as its collector load. Q_3 and the relay thus turn on and off in sympathy with Q_2 collector voltage. As the relay operates, it turns panel light LP_1 on and off via contact *RLA/1*, again in sympathy with Q_2 collector. D_7 prevents the relay coil switch-off back-e.m.f.s from damaging the transistor circuitry.

Now assume that the short is removed from between Q_4 collector and the 0 V line, as in Fig. 6.1, and that an independent positive input voltage is applied between each input terminal and ground (0 V line). Q_4 is wired as a common emitter amplifier, using the entire Q_1–Q_2 circuit as its collector load, and has its base bias provided via R_6 and the diode input network; a +ve bias of more than 4.5 V is needed at one or more of the input terminals to turn Q_4 on.

Suppose, then, that all inputs are at a potential of considerably less than 4.5 V. In this case Q_4 is cut off through lack of base current, and thus passes zero collector current; zero current thus flows to the Q_1–Q_2 circuitry and to Q_3 base, so the entire Q_1–Q_2–Q_3 circuit is inoperative

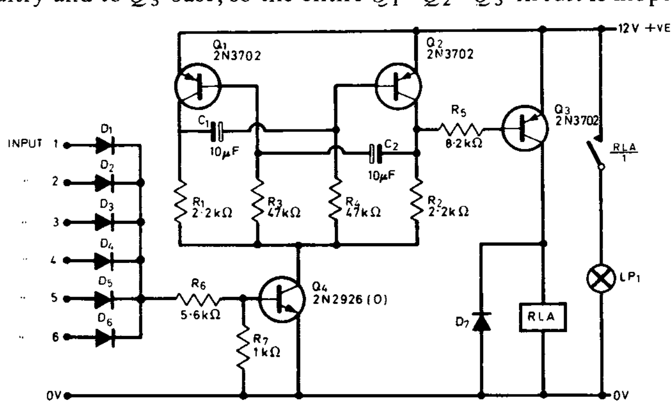

Fig. 6.1. Negative ground version of the unit

and the relay and lamp are off. The circuit passes a total leakage current of only a few micro-amps under this condition.

Suppose now that (say) input 1 is raised to 12 V +ve, but that all other inputs are at less than 4.5 V. In this case D_1 becomes forward biased and drives Q_4 hard on via R_6, so Q_4 collector is effectively shorted to the 0 V line; the Q_1-Q_2 and Q_3 circuits thus operate normally under this condition, so *RLA* and the panel light are switched alternately on and off, indicating that a high voltage is applied at one of the inputs. The remaining input diodes are reverse biased under this condition, however, so the input 1 voltage does not appear at any of the other input terminals. Similar circuit action takes place whenever a high voltage is connected at any one or more of the units input terminals. The unit can be made to accept more (or fewer) inputs by simply adding (or removing) input diodes, as required.

Since the input voltages of the unit are obtained from the warning lamps of other units, and these lamps are either full on or full off, the unit's input voltages are at either 0 V or 12 V +ve. The main panel light is thus normally fully off, but flashes alternately on and off whenever one or more of the warning lights is illuminated; as the relay turns on and off, its moving parts emit a series of clicks, thus giving a clearly audible warning of circuit operation.

The positive ground version of the unit is shown in Fig. 6.2. Circuit operation is identical with that described above, except that all circuit polarities are reversed, and that npn transistors are used in place of pnp types, and vice versa.

Construction and use

The circuit, less *RLA*, is wired up on a 2¾ x 1½ in piece of Veroboard panel with 0.15 in hole spacing. Fig. 6.3 shows the constructional details for the 6-input positive ground version of the unit. Construction of the negative ground version is identical, except that the polarities of all capacitors, diodes, and supply leads are reversed. If fewer inputs than six are needed, remove excess input diodes, as required. Relay *RLA* can be any type with a coil resistance greater than 120 Ω and with one or more N/O contacts; it must, however, be capable of operating positively at *less* than 8.5 V.

When construction is complete (Plate 6.1), mount the panel and the relay in a suitable case; if a metal case is used, bond a couple of small rubber grommets to the underside of the panel, one below each mounting hole, to act as spacer/insulators to prevent the copper strips shorting to the case. The unit can now be given a functional test, as follows.

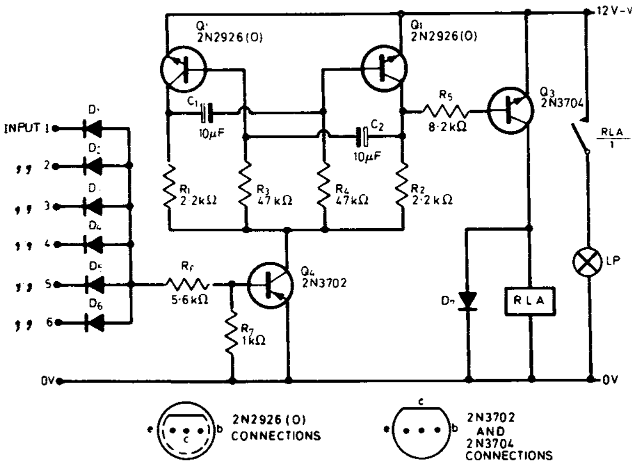

Fig. 6.2. Positive ground version of the unit, plus transistor connections

Components list (both versions) (Figs. 6.1 and 6.2)

R_1	=	2.2 kΩ,	¼ W	
R_2	=	2.2 kΩ,	¼ W	
R_3	=	47 kΩ,	¼ W	
R_4	=	47 kΩ,	¼ W	
R_5	=	8.2 kΩ,	¼ W	
R_6	=	5.6 kΩ,	¼ W	
R_7	=	1 kΩ,	¼ W	
C_1	=	10 μF,	18 V	electrolytic
C_2	=	10 μF,	18 V	electrolytic
RLA	=	Relay with coil resistance greater than 120 Ω, one or more N/O contacts; relay must be capable of operating at less than 8.5 V		
LP_1	=	12 V, 2 W or greater panel lamp		
D_1–D_7	=	general purpose silicon diodes		
Q_1–Q_2	=	2N3702	(Texas) (–ve ground version)	
	=	2N2926, orange coded (G.E.) (+ve ground version)		
Q_3	=	2N3702	(–ve ground version)	
	=	2N3704	(+ve ground version)	
Q_4	=	2N2926(0)	(–ve ground version)	
	=	2N3702	(+ve ground version)	
		Veroboard, hook-up wire, etc.		

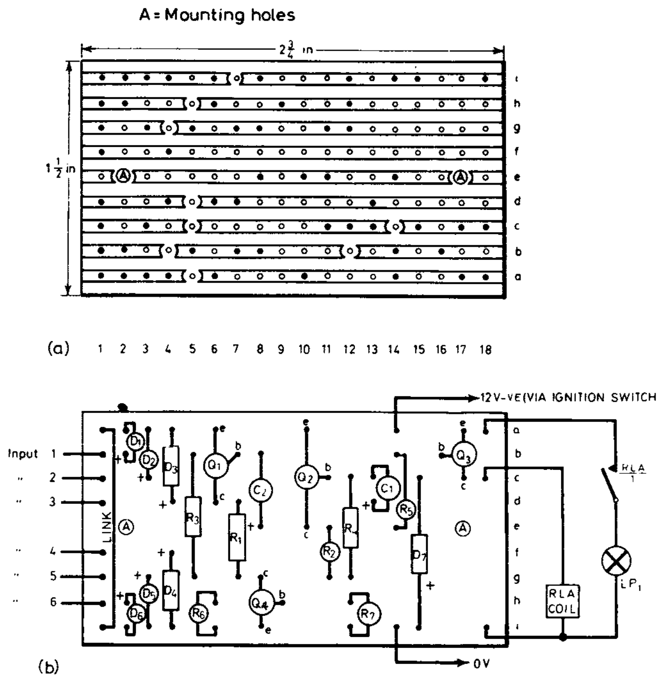

Fig. 6.3. Veroboard arrangement
(a) Copper side
(b) Component assembly on plain side (+ve ground version only)

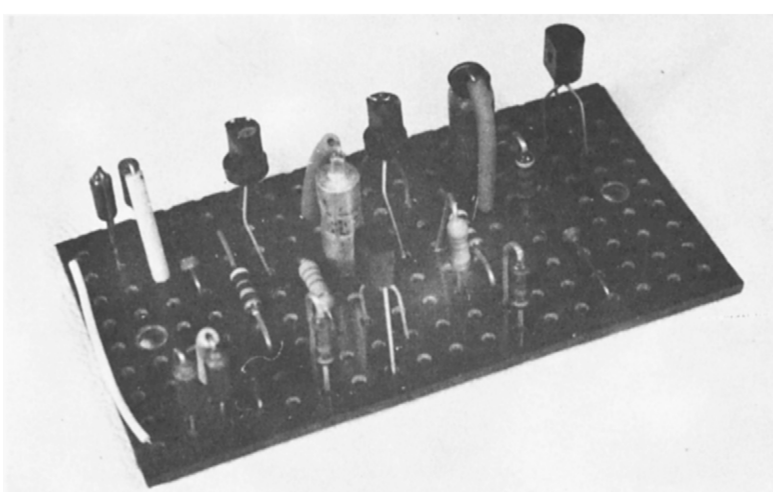

Plate 6.1

Wire the unit to the car battery, short input 1 to the 12 V line, and check that the relay operates and that LP_1 flashes on and off; the flashing rate can be increased (or reduced), if required, by reducing (or increasing) the values of R_3 and R_4, down to a minimum value of 22 k (or up to a maximum value of 100 k). Remove the input 1 connection, and check that LP_1 goes off. If satisfactory, repeat the test on inputs 2, 3, 4, 5 and 6. The unit is then complete and ready for use, and can be permanently wired up to the vehicle; the final connection to the battery should preferably be made via the ignition switch.

In use, the input terminals of the unit are wired directly to the 'hot' end of the warning lamps of the different units described in later sections of this volume.

Project 7

ICE-WARNING INDICATOR

This unit automatically operates a small warning light on the car's instrument panel whenever there is a danger of ice on the road. The device uses a thermistor to sense the air temperature just above the road surface, and closes an electronic switch whenever this temperature falls below 0°C. The design is such that the operating point of the electronic switch is independent of the temperature of the actual transistor circuitry, and of variations in the car's battery voltage. The thermal backlash of the circuit is a mere 0.5°C, i.e., the electronic switch closes when the thermistor temperature falls to 0°C, and opens again when it rises to +0.5°C.

How it works

Fig. 7.1 shows the negative ground version of the unit, in which one side of the indicator lamp is taken to the car's chassis. The circuit is made up of two sections, the first being a temperature-sensing differential amplifier (Q_1 and Q_2), and the second being a regenerative switch (Q_2 and Q_3). The temperature-sensing section operates as follows.

Q_1 and Q_2 operate basically as emitter followers, but share a common emitter resistor, R_3. Q_1 base potential is fixed at half supply line voltage by potential divider R_1–R_2, and Q_2 base potential depends

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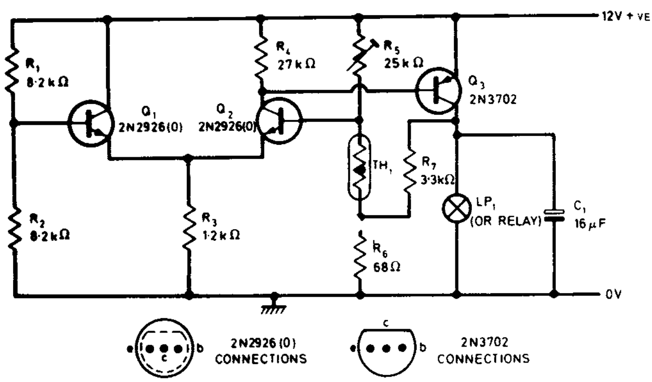


Fig. 7.1. Circuit and transistor connections of –ve ground version of the unit

on the values of R_5 and TH_1. TH_1 is a carbon rod thermistor, and acts as a temperature-sensitive resistor; it has a resistance of about 4.7 kΩ at 25°C, and rises to about 12 kΩ when the temperature falls to 0°C. Thus, the Q_2 base voltage rises as the TH_1 temperature falls. R_5 is adjusted so that the Q_2 base potential is the same as that of Q_1 when the thermistor is at 0°C.

Now, due to the emitter follower actions of Q_1 and Q_2, the voltage at the top of R_3 inevitably takes up a value close to that of the larger of the two base voltages. Consequently, when Q_2 base voltage is lower than that of Q_1 (TH_1 temperature above 0°C), both emitters are held at approximately 6 V by Q_1. The base-emitter junction of Q_2 is therefore reverse biased under this condition, so Q_2 is cut off and passes zero collector current. When, on the other hand, Q_2 base voltage is above that of Q_1 (TH_1 temperature below 0°C), the two emitter voltages are controlled by Q_2, so Q_2 is turned on and passing collector current under this condition, and Q_1 is cut off. The Q_2 base voltage changes by about 250 mV per degree C of TH_1 temperature at around 0°C, so the temperature variation needed to turn Q_2 from the *off* to the *on* state is very small.

Referring again to Fig. 7.1, the collector current of Q_2 is fed into the base of common emitter amplifier Q_3, which drives a lamp or relay collector load; part of the Q_3 collector voltage is also fed back to the R_6–TH_1 junction via R_7. Thus, at temperatures above 0°C, Q_2 passes zero collector current, so no base current flows to Q_3, and this transistor is cut off. Since Q_3 is cut off, negligible voltage is developed across its collector load, so the lamp (or relay) is off also.

When, on the other hand, the thermistor temperature falls to zero, and Q_2 just begins to conduct, the resulting Q_2 collector current just starts to turn Q_3 on. As Q_3 starts to go on, its collector moves towards the +ve rail potential, and a fraction of this rising voltage is fed back to

the TH_1-R_6 junction via R_7, and causes Q_2 base voltage to increase. This increased base voltage turns Q_2 and Q_3 on even harder, and causes a regenerative action to take place, and Q_3 is driven rapidly to saturation. The lamp(or relay) is thus turned on. The feedback voltage obtained via R_7 is only just sufficient to maintain regeneration during the switching stage, so the circuit has very little thermal backlash. C_1 ensures that supply line transients do not cause erratic triggering of the circuit.

Since the base bias networks of Q_1 and Q_2 are both connected across a common supply line, changes in supply voltage affect both transistors equally; the trigger points of the circuit are thus independent of variations in supply line potential. Similarly, the differential actions of Q_1 and Q_2 ensure that the trigger levels are unaffected by variations in the temperature of the actual transistor circuitry. The circuit is thus exceptionally stable in operation, and exceptionally sensitive to changes in thermistor temperature.

The positive ground version of the unit is shown in Fig. 7.2, and operates in a manner identical to that described above. If it is not important that one side of the panel lamp (or relay) is grounded, or the unit is not to be used in conjunction with the panel light flasher of Project 6, either version of the unit can in fact be used in any car by simply wiring the supply leads to the car battery in the correct polarity. If the unit is to be used in conjunction with Project 6, however, it is imperative that the correct version be used in the car in question. If a relay is to be used in place of LP_1, it must have a coil resistance greater than 120 Ω, and a diode wired across the coil.

Construction and use

The major part of the circuit, less TH_1 and the panel light (or relay), is wired up on a 2½ x 1⅛ in piece of Veroboard panel with 0.15 in hole spacing. Fig. 7.3 shows constructional details of the +ve ground version of the unit. The –ve ground version is identical, except that the polarity of C_1 and the supply leads are reversed. A photograph of the unit is shown in Plate 7.1.

When construction is complete, wire the unit temporarily to the car battery and to LP_1 (or the relay) and TH_1, and carry out a simple functional test, as follows. Check that the lamp can be turned on and off by adjusting R_5, and then carefully adjust R_5 so that the lamp just turns on at the prevailing temperature; now raise the TH_1 temperature slightly, using either finger heat or the heat from a cigarette, and check that the lamp goes off, and then goes on again shortly after the heat is removed. If satisfactory, the unit can now be permanently installed in the vehicle.

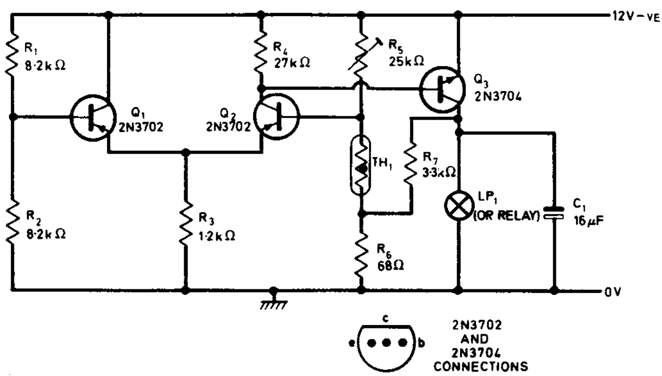


Fig. 7.2. Circuit and transistor connections of +ve ground version of the unit

Components list (Fig. 7.2)

R_1	=	8.2 kΩ,	¼ W
R_2	=	8.2 kΩ,	¼ W
R_3	=	1.2 kΩ,	¼ W
R_4	=	27 kΩ,	¼ W
R_5	=	25 kΩ,	skeleton pre-set, vertical mounting
R_6	=	68 Ω,	¼ W
R_7	=	3.3 kΩ,	¼ W

TH_1 = carbon rod thermistor
Resistance = approx. 4.7 kΩ at 25°C
= approx. 12 kΩ at 0°C
i.e., Mullard VA1066S
R.C.A. KD2108
etc.

Q_1–Q_2 = 2N2926, orange coded (G.E.) (–ve ground version)
= 2N3702 (Texas) (+ve ground version)

Q_3 = 2N3702 (Texas) (–ve ground version)
= 2N3704 (Texas) (+ve ground version)

LP_1 = 12 V, 40 mA lamp

Relay = 12 V type, coil resistance greater than 120 Ω

C_1 = 16 μF, 15 V electrolytic

Veroboard, hook-up wire, etc.

The finished unit can be mounted under the car's instrument panel, and should have its upper supply lead taken to the battery via the ignition switch, so that it operates only when the ignition is turned on. The thermistor itself is mounted in a small 'head' that is fixed to the lower front of the vehicle, and is connected to the main unit via twin flex. To make the thermistor head, fix TH_1 to a small piece of Veroboard, and then solder its leads to the twin flex; coat the whole assembly with waterproof varnish, so that moisture will not affect its apparent resistance, and then mount it in a small plastics or metal box and fix it to the lower front of the car; before fixing the head in place, however, calibrate the unit as follows.

Immerse the head in a small container filled with a water and ice mixture; use a thermometer to measure the temperature of the mixture, and add ice until a steady reading of 0°C is obtained. Now adjust R_5 so that the panel lamp just turns on; raise the temperature slightly, and check that the lamp goes off again. If satisfactory, calibration is now complete, and the head can be permanently fixed to the vehicle.

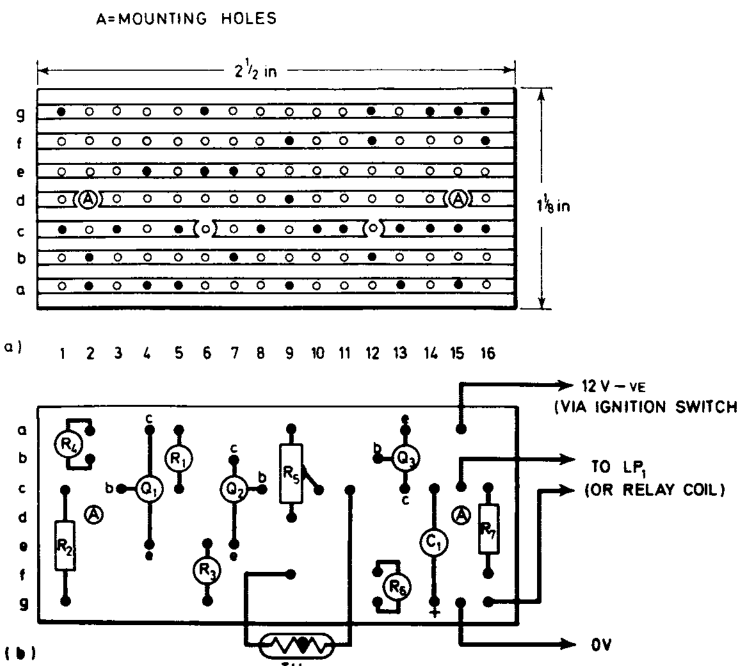


Fig. 7.3. Veroboard arrangement
(a) Copper side
(b) Component assembly on plain side +ve ground version (see text for –ve ground version)

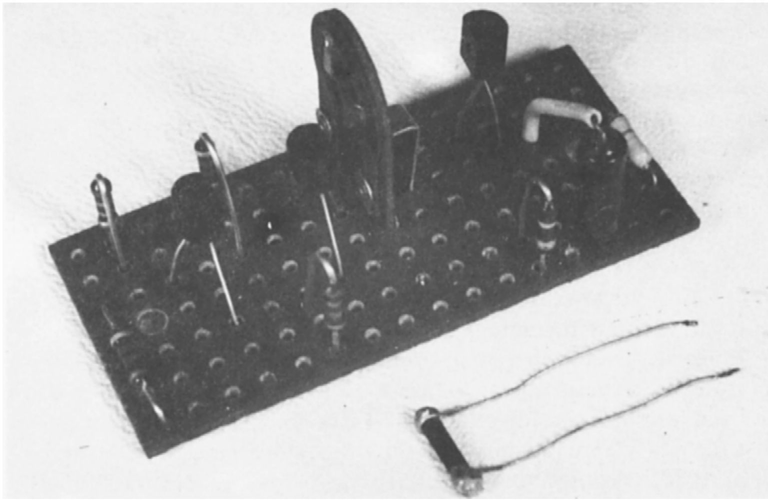


Plate 7.1

If the ice-warning indicator is to be used in conjunction with the panel light flasher of Project 6, connect Q_3 collector to one of the input leads of Project 6.

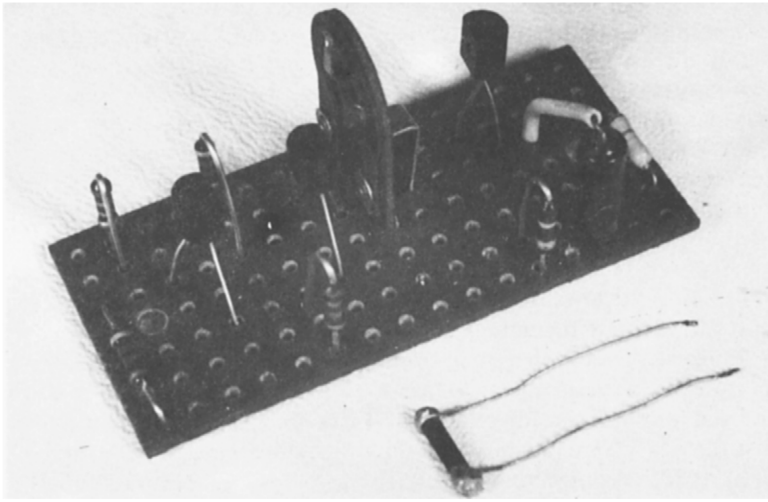
Project 8

OVER-HEAT INDICATOR

This device operates a small warning light whenever the temperature of a thermistor probe exceeds a pre-set value. The probe can be bonded to any fixed part of the vehicle. The unit can thus be used to warn the driver if overheating occurs in the car engine, gearbox, differential, or brake drums, etc. The thermal switching point of the unit is independent of the temperature of the actual transistor circuitry, and of variations in the car battery voltage. The thermal backlash of the circuit is typically about 1°C.

How it works

Fig. 8.1 shows the negative ground version of the unit, in which one side of the indicator lamp (or relay coil) is taken to the car chassis. The



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How it works

Fig. 8.1 shows the negative ground version of the unit, in which one side of the indicator lamp (or relay coil) is taken to the car chassis. The

circuit is similar to that described in Project 7, and is made up of two sections. One section is a temperature-sensing differential amplifier (Q_1 and Q_2), and the other is a regenerative switch (Q_2 and Q_3). The temperature-sensing section operates as follows.

Q_1 and Q_2 are wired as emitter followers, but share a common emitter resistor, R_2. The base potential of Q_1 is determined by potential divider R_1-TH_1, and that of Q_2 is determined by potential divider $R_4-R_5-R_6$. TH_1 is a carbon rod thermistor, and acts as a

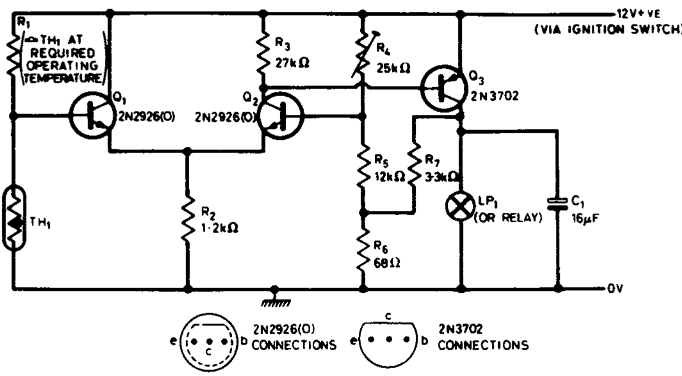

Fig. 8.1. Circuit and transistor connections of –ve ground version of the unit

Components list (Figs. 8.1 and 8.2)

R_1	=	approximately same resistance as TH_1 at required operating temperature (see text), ¼ W	
R_2	=	1.2 kΩ,	¼ W
R_3	=	27 kΩ,	¼ W
R_4	=	25 kΩ,	skeleton pre-set, vertical mounting
R_5	=	12 kΩ,	¼ W
R_6	=	68 Ω,	¼ W
R_7	=	3.3 kΩ,	¼ W
TH_1	=	carbon rod thermistor Resistance = approx. 40 kΩ to 200 kΩ at 25°C = approx. 1 kΩ to 3.3 kΩ at 150°C i.e., Mullard VA1056S VA1067S R.C.A. KD2109 etc.	
Q_1–Q_2	=	2N2926, orange coded (G.E.) (–ve ground version)	
	=	2N3702 (Texas) (+ve ground version)	
Q_3	=	2N3702 (Texas) (–ve ground version)	
	=	2N3704 (Texas) (+ve ground version)	
LP_1	=	12 V, 40 mA lamp	
Relay	=	12 V type, coil resistance greater than 120 Ω	
C_1	=	16 μF, 15 V electrolytic	
		Veroboard, hook-up wire, etc.	

resistor that decreases in value as its temperature increases. Thus, Q_1 base voltage is high at normal temperatures, but decreases as temperature rises. R_1 is selected to have roughly the same resistance as TH_1 at the desired operating temperature, and R_4 is adjusted so that the two base potentials are exactly equal (at about 6 V) at the desired temperature.

Now, due to the emitter follower actions of Q_1 and Q_2, the voltage at the top of R_2 inevitably takes up a value close to that of the larger of the two base voltages. Consequently, if the two base voltages differ by more than a few tens of millivolts, the transistor with the higher base voltage is biased on and causes the base-emitter junction of the other transistor to be reverse biased, so that that transistor is cut off. When, on the other hand, the two base voltages are equal, both transistors are biased on. Hence, Q_1 is biased on and Q_2 is cut off when the TH_1 temperature is below the pre-set value, but Q_2 turns on as soon as the thermistor reaches the pre-set value. When the temperature is above the pre-set value, Q_2 is on and Q_1 is cut off.

Referring again to Fig. 8.1, the collector current of Q_2 is fed into the base of Q_3, and Q_3 drives a lamp or relay load in its collector circuit; part of the Q_3 collector voltage is also fed back to the R_5-R_6 junction via R_7. Thus, at TH_1 temperatures below the pre-set value Q_2 passes zero collector current, so Q_3 is cut off, and the lamp (or relay) is off also.

When, on the other hand, the temperature reaches the pre-set value, Q_2 starts to conduct and thus starts to drive Q_3 on. As Q_3 starts to go on its collector moves towards the +ve rail potential, and a fraction of this rising voltage is fed back to the R_5-R_6 junction via R_7, and causes Q_2 base voltage to increase. This increased base voltage turns Q_2 and Q_3 on even harder. A regenerative action thus takes place, and Q_3 is driven rapidly to saturation and the lamp (or relay) goes on. The feedback voltage obtained via R_7 is only just sufficient to maintain regeneration during the switching stage, so the circuit has very little thermal backlash. Backlash is typically about 1°C, i.e., if the lamp goes on when the TH_1 temperature rises to 100°C, it goes off again when the temperature falls to 99°C.

Since Q_1 and Q_2 are connected in the differential mode, variations in battery voltage and circuit temperature affect both transistors equally. The thermal trigger point of the circuit is therefore dictated purely by the TH_1 temperature, and is independent of circuit temperature and battery voltage. Exceptionally stable circuit operation and high sensitivity are thus available. C_1 ensures that supply line transients do not cause erratic triggering of the circuit.

The positive ground version of the unit is shown in Fig. 8.2, and operates in a manner similar to that described above. If it is not important that one side of the panel lamp (or relay) is grounded, or the unit is

not to be used in conjunction with the panel light flasher of Project 6, either version of the unit can in fact be used in any car by simply wiring the supply leads to the car battery in the correct polarity. If the unit is to be used in conjunction with Project 6, however, it is imperative that

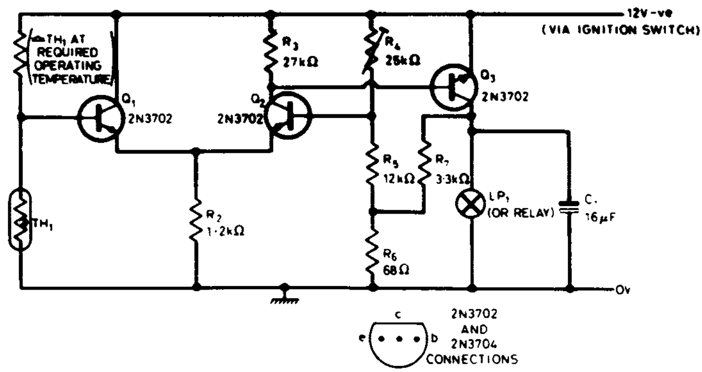

Fig. 8.2. Circuit and transistor connections of +ve ground version of the unit

the correct version be used in the car in question. Relay *RLA* must have a coil resistance greater than 120 Ω, if used, and a diode wired across the coil.

Construction and use

The major part of the circuit, less TH_1 and the panel light (or relay), is wired up on a 2½ x 1⅛ in piece of Veroboard panel with 0.15 in hole spacing. Fig. 8.3 shows constructional details of the +ve ground version of the unit. The –ve ground version is identical, except that the polarity of C_1 and the supply leads are reversed. A photograph of the unit is shown in Plate 8.1.

R_1 must have a value roughly equal to that of TH_1 at the required trigger temperature. The resistance of TH_1 roughly halves with every 20°C increase in temperature, so if TH_1 is (say) a Mullard 1056S, which has a resistance of about 47 k at 25°C, and the circuit is required to trip at 95°C, R_1 should have a value of about 4.7 k. Precise values of R_1 are not important, as R_4 enables considerable errors to be compensated for. TH_1 can be any negative temperature coefficient carbon rod thermistor with a resistance in the range 40 k to 200 k at 25°C, or 1 k to 3 k at 150°C.

When construction is complete, wire the unit to the car battery via the ignition switch, connect up LP_1 (or the relay), and temporarily wire the thermistor in place. Now give the unit a functional test, as follows.

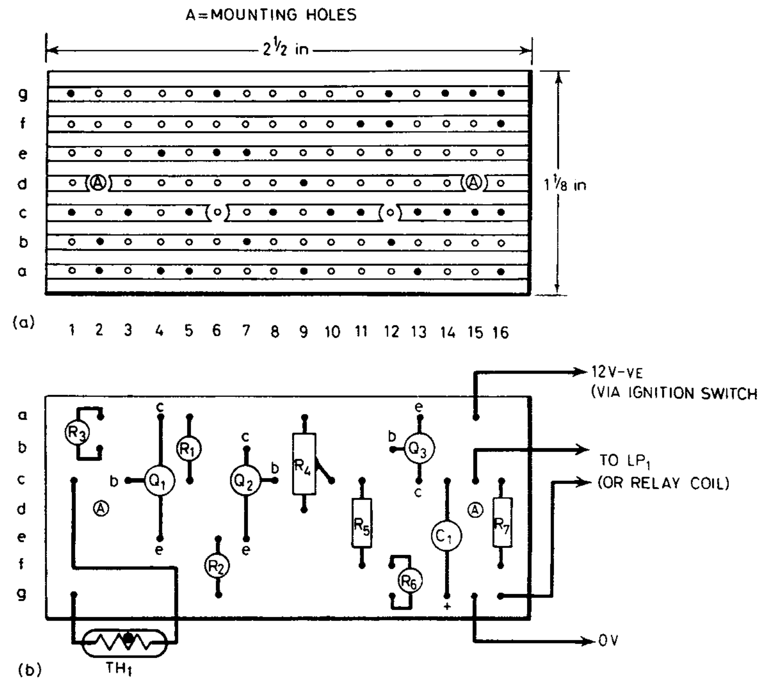

Fig. 8.3. Veroboard arrangement
(a) Copper side
(b) Component assembly on plain side +ve ground version (see text for –ve ground version)

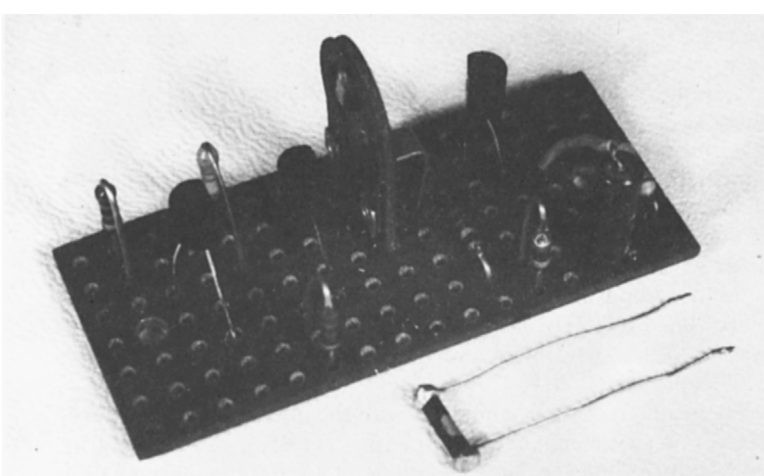

Plate 8.1

Turn on the ignition, raise the TH_1 temperature to the required over-heat value, and adjust R_4 so that LP_1 just goes on. Now reduce the TH_1 temperature slightly, and check that the lamp goes off. If satisfactory, the thermistor can then be permanently bonded to the surface whose temperature is to be monitored (i.e., engine, gearbox, brake drums, etc.), using epoxy resin or 'plastic metal'. The unit is then complete and ready for use.

If the unit is to be used in conjunction with the panel light flasher of Project 6, connect Q_3 collector to one of the input leads of Project 6.

Project 9

LOW-FUEL-LEVEL INDICATOR

This device is activated by the car's fuel level gauge, and operates a small warning light when the fuel level falls below a pre-set value. Alternatively, the unit can be made to operate the panel light if the engine water temperature exceeds a pre-set value, provided that the vehicle is fitted with an electrically operated water temperature gauge. The device is, in fact, a voltage-operated electronic switch which turns on whenever the input voltage falls below a pre-set value.

How it works

Fig. 9.1 shows the negative ground version of the unit. The circuit is similar to that described in Project 7, and is made up of a voltage-

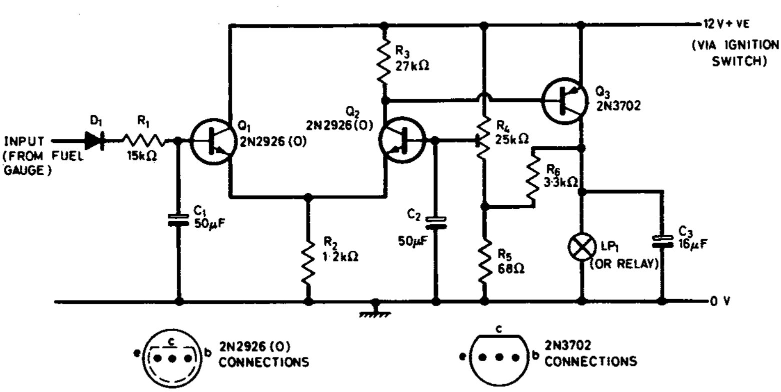

Fig. 9.1. Circuit and transistor connections of –ve ground version of the unit

Turn on the ignition, raise the TH_1 temperature to the required over-heat value, and adjust R_4 so that LP_1 just goes on. Now reduce the TH_1 temperature slightly, and check that the lamp goes off. If satisfactory, the thermistor can then be permanently bonded to the surface whose temperature is to be monitored (i.e., engine, gearbox, brake drums, etc.), using epoxy resin or 'plastic metal'. The unit is then complete and ready for use.

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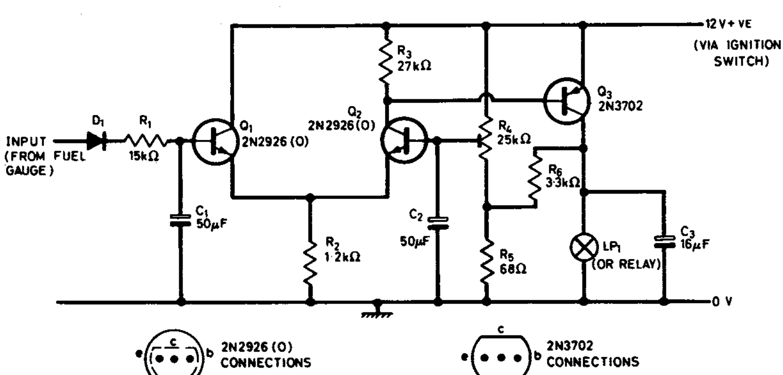

Fig. 9.1. Circuit and transistor connections of –ve ground version of the unit

sensing differential amplifier (Q_1 and Q_2), and a regenerative switch (Q_2 and Q_3). The differential section operates as follows.

Q_1 and Q_2 are wired as emitter followers, but share a common emitter resistor, R_2. An external voltage (derived from the car's fuel or water-temperature gauge) is applied to Q_1 base via D_1 and R_1, and the base voltage of Q_2 is determined by R_4. Due to the emitter follower actions of Q_1 and Q_2, the voltage at the top of R_2 takes up a value close to that of the larger of the two base voltages. Consequently, if the base voltages differ by more than a few tens of millivolts, the transistor with the higher base voltage is driven on and causes the base-emitter junction of the other transistor to be reverse biased, so that transistor is cut off. When, on the other hand, the two voltages are equal, both transistors are biased on. Thus, Q_2 goes on only when the Q_1 base voltage is equal to or less than that of Q_2: D_1-R_1 and C_1 form a simple smoothing network, so that the Q_1 base voltage corresponds to mean, rather than instantaneous, input voltages.

Referring again to Fig. 9.1, the collector current of Q_2 is fed into the base of Q_3, and Q_3 drives a lamp or relay load in its collector circuit; part of the Q_3 collector voltage is also fed back to the R_4-R_5 junction via R_6. Thus, when the Q_1 base voltage is above that of Q_2, Q_2 and Q_3 and the lamp (or relay) are off.

When, on the other hand, the two voltages are nearly equal, Q_2 starts to conduct, and thus starts to drive Q_3 on. As Q_3 starts to go on its collector moves towards the +ve rail potential, and a fraction of this rising voltage is fed back to the R_4-R_5 junction via R_6, and causes Q_2 base voltage to increase. This increased base voltage turns Q_2 and Q_3 on even harder. A regenerative action thus takes place, and Q_3 is driven rapidly to saturation and the lamp (or relay) goes on. The feedback voltage obtained via R_6 is only just sufficient to maintain regeneration during the switching stage, so the circuit has very little trigger voltage backlash. Thus, the lamp (or relay) is normally off, but switches sharply on as soon as the input voltage falls below a pre-set mean value determined by R_4. C_2 ensures that the circuit is not triggered by moderately rapid changes in battery voltage (due to sudden variations in engine speed), and C_3 ensures that the circuit is not triggered erratically by supply line transients.

The positive ground version of the unit is shown in Fig. 9.2, and operates in a manner similar to that described above.

Now, most cars are fitted with a fuel gauge of the type shown in Fig. 9.3a, in which a float-driven potentiometer is wired in series with a hot-wire meter, and in which the potentiometer voltage is proportional to the fuel level, i.e., it decreases as fuel level falls. Similarly, many cars are also fitted with electrically operated water temperature gauges of the type shown in Fig. 9.3b, in which an engine-mounted thermistor is wired in series with a hot-wire meter, and in

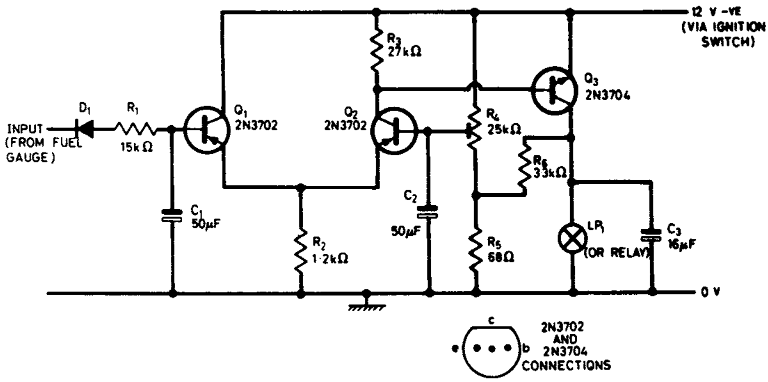

Fig. 9.2. Circuit and transistor connections of +ve ground version of the unit

Components list (Figs. 9.1 and 9.2)

R_1	=	15 kΩ,	¼ W	
R_2	=	1.2 kΩ,	¼ W	
R_3	=	27 kΩ,	¼ W	
R_4	=	25 kΩ,	skeleton pre-set, vertical mounting	
R_5	=	68 Ω,	¼ W	
R_6	=	3.3 kΩ,	¼ W	
LP_1	=	12 V,	40 mA lamp	
Relay	=	12 V type, coil resistance greater than 120 Ω		
C_1	=	50 μF,	15 V	electrolytic
C_2	=	50 μF,	15 V	electrolytic
C_3	=	16 μF,	15 V	electrolytic
Q_1–Q_2	=	2N2926, orange coded (G.E.) (−ve ground version)		
	=	2N3702	(Texas) (+ve ground version)	
Q_3	=	2N3702	(Texas) (−ve ground version)	
	=	2N3704	(Texas) (+ve ground version)	
D_1	=	general purpose silicon diode		
		Veroboard, hook-up wire, etc.		

which the thermistor voltage is inversely proportional to water temperature, i.e., voltage falls as temperature rises. Consequently, by connecting one or other of these voltages to the input of Fig. 9.1, the unit can be made to operate the lamp (or relay) when either the fuel level falls below a pre-set value, or the water temperature exceeds a pre-set value.

Construction and use

Before starting construction, check that the vehicle is fitted with the correct type of gauge for operating the unit. If it is to be used as a low-

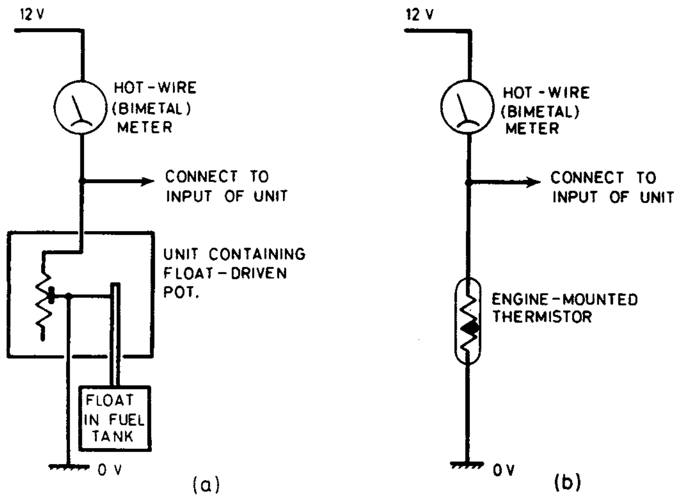

Fig. 9.3. Circuit of typical fuel level gauge (a) and water temperature gauge (b) and method of connecting to the electronic unit

fuel-level indicator, check that the voltage across the float-driven potentiometer (see Fig. 9.3a) falls with fuel level, and is above 1.5 V at the required operating level. If it is to be used as an excess-water-temperature indicator, check that the voltage across the thermistor (see Fig. 9.3b) falls as temperature rises, and is above 1.5 V at the required operating level.

The circuit, less the lamp (or relay), is wired up on a 2½ x 1⅛ in piece of Veroboard panel with 0.15 in hole spacing. Fig. 9.4 shows constructional details of the +ve ground version of the unit. The –ve ground version is similar, except that the polarities of D_1, C_1, C_2, C_3, and the supply leads are reversed. A photograph of the finished panel is shown in Plate 9.1.

When construction is complete, wire the unit to the car battery via the ignition switch, connect up LP_1 (or the relay), and test and adjust the unit as follows. Reduce the fuel level in the petrol tank to the required trip value (or, if the unit is to be used as an excess-water-temperature indicator, raise the thermistor temperature to the required level), connect the unit's input to the gauge as shown in Fig. 9.3, and turn on the ignition. Now very slowly adjust R_4 so that LP_1 (or the relay) just goes on. Next, slightly increase the fuel level (or reduce the thermistor temperature) and check that LP_1 goes off. Finally, re-check the adjustment; when satisfactory, the unit is complete and ready for use.

The finished unit can, if required, be used in conjunction with the

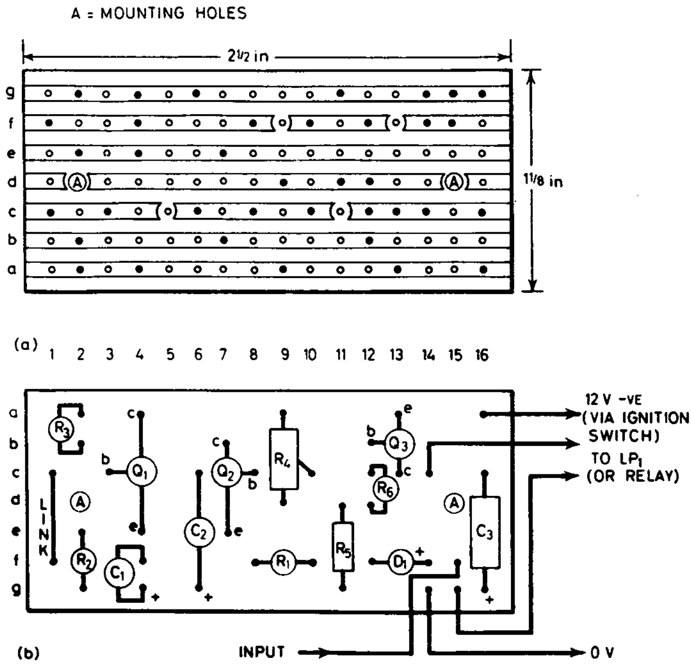

Fig. 9.4. Veroboard arrangement
(a) Copper side
(b) Component assembly on plain side +ve ground version (see text for –ve ground version)

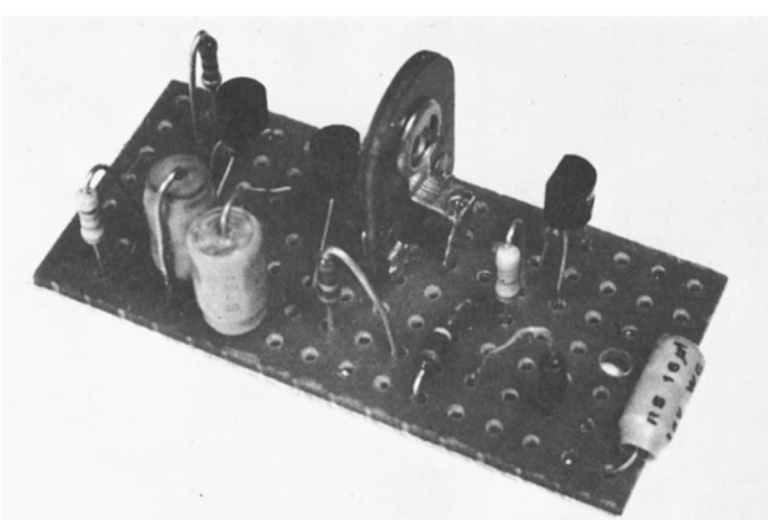

Plate 9.1

panel light flasher of Project 6 by connecting Q_3 collector to one of the input leads of Project 6.

Note that, when the unit is used as a low-fuel-level indicator, the indicator in practice first starts to operate (for limited periods) when the instantaneous fuel level is slightly above the pre-set mean value; this occasional operation usually occurs under conditions of sharp acceleration or cornering, and is due to sustained gravitational changes in fuel level (operation is not effected by normal fuel splashing). This phenomenon only occurs when the mean fuel level is close to the pre-set value, however, and is thus advantageous, since it gives the driver an advanced indication that fuel is running low. The phenomenon can be eliminated, if required, by increasing the value of R_5, by trial and error, to increase circuit backlash.

Project 10

EMERGENCY-LIGHT FLASHER

When in use, this unit switches all four of the cars turn-indicator (flasher) lamps on and off at the same time, at a rate of about 70 flashes per minute; the device is intended to be used only when the vehicle is broken down or damaged by the roadside, thus giving approaching cars a warning of the emergency. The circuitry is quite simple, and can be built and installed in a single evening.

How it works

Fig. 10.1 shows the circuit of the normal flasher or turn-indicator system fitted in negative ground vehicles. The circuit is operative only when the ignition switch is turned *on*, and when the turn-indicator switch is moved to the *left* or *right* position. Note that the turn-indicator lamps, LP_1 –LP_4, are connected in two independent groups.

Fig. 10.2a shows how these two independent groups of lamps must be connected to act as emergency-light flashers in –ve ground vehicles. Here, a relay-driving electronic flasher unit turns relay *RLA* on and off at a rate of about 70 operations per minute when S_3 is closed. When S_3 is open the flasher is inoperative, and relay contacts *RLA/1* and *RLA/2* are open; the two groups of lamps are isolated from one another by

panel light flasher of Project 6 by connecting Q_3 collector to one of the input leads of Project 6.

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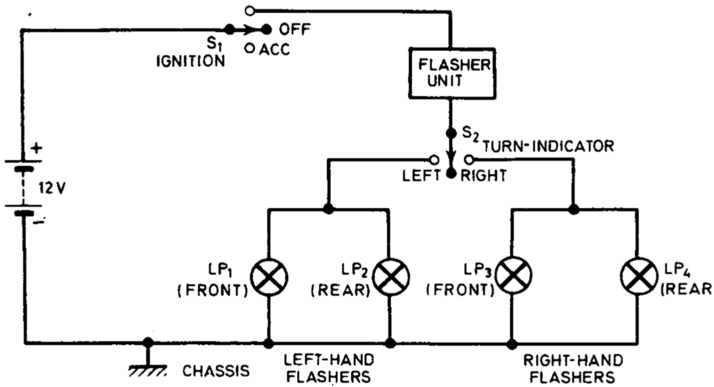

Fig. 10.1. Normal flasher (turn-indicator) circuit, −ve ground vehicle

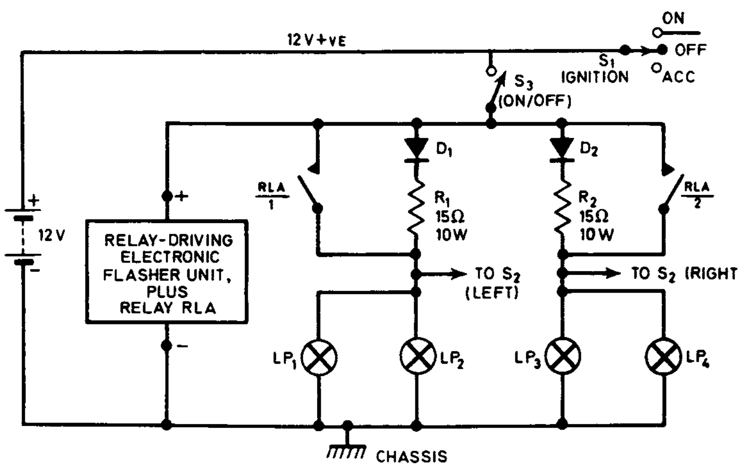

Fig. 10.2a. Method of connecting emergency-light flasher in −ve ground vehicles

D_1 and D_2 under this condition, and can thus operate normally as turn-indicator lamps.

Suppose now that S_3 is closed, and the flasher unit is operating the relay. When the relay is in the *off* period of operation, contacts *RLA/1* and *RLA/2* are open; a 'pre-heat' current of about 800 mA flows directly from the car battery to each group of lamps, via $D_1 - R_1$ and $D_2 - R_2$, under this condition; this current is too low to give illumination of the lamps, however, so the lamps are effectively *off* under this condition. When, on the other hand, the relay is in the *on* period of operation, contacts *RLA/1* and *RLA/2* are closed, so the two groups of lamps are shorted directly to the car battery, and all four

lamps operate at full brilliance. The four lamps thus continuously flash on and off together when S_3 is closed, even if the ignition is turned off.

Fig. 10.2b shows how the emergency-light flasher system is connected in +ve ground vehicles. The circuit is identical to that described above, except that the polarities of D_1, D_2, and the supply leads of the electronic flasher unit, are reversed.

The pre-heat currents that flow in the lamps when S_3 is closed and the relay is off are intended to keep the filaments sufficiently hot to keep surge currents reasonably low when the lamps are turned full on again, thus extending the operating life of the lamps; a similar pre-heating function is performed by the electro-mechanical flasher unit used for operating the normal turn-indicator lamps (Fig. 10.1).

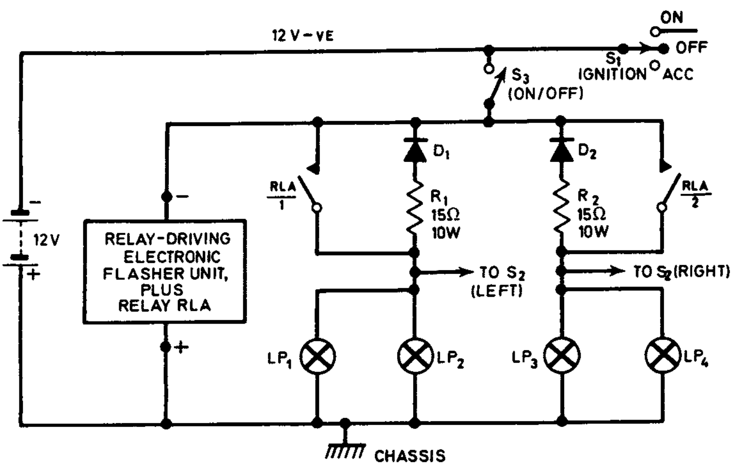

Fig. 10.2b. Method of connecting emergency-light flasher in +ve ground vehicles

Fig. 10.3 shows the circuit of the actual relay-driving electronic flasher unit. This is a simple astable multivibrator, driving *RLA* via common emitter amplifier Q_3. Diodes D_3 and D_4 prevent base-emitter breakdown of Q_1 and Q_2 when the astable is operating, and thus enhance timing stability. D_5 ensures that switch-off back e.m.f.s from the relay coil do not damage Q_3. The *on* and *off* times of the circuit are controlled by time-constants $C_1 - R_6$ and $C_2 - R_5$.

Construction and use

The electronic flasher unit, less the relay, is wired up on a 2½ x 1⅛ in piece of Veroboard panel with 0.15 in hole spacing. Fig. 10.4 shows

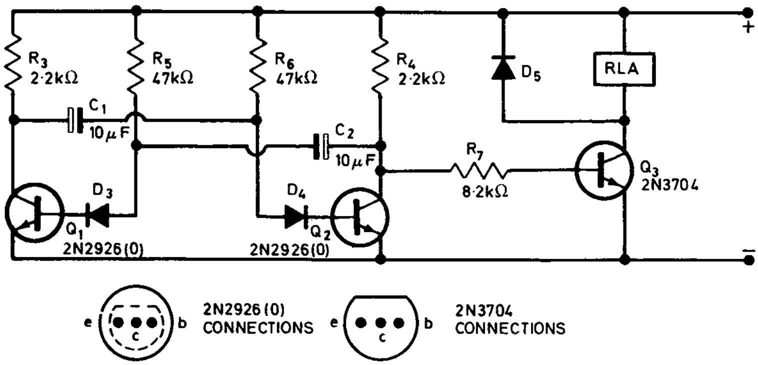

Fig. 10.3. Circuit of the electronic flasher unit

Components list (Fig. 10.3)

R_1 =	15 Ω,	10 W	wire-wound
R_2 =	15 Ω,	10 W	
R_3 =	2.2 kΩ,	¼ W	
R_4 =	2.2 kΩ,	¼ W	
R_5 =	47 kΩ,	¼ W	
R_6 =	47 kΩ,	¼ W	
R_7 =	8.2 kΩ,	¼ W	
C_1–C_2 =	10 μF,	15 V	electrolytic
S_3 =	5 A,	on/off switch	
Q_1–Q_2 =	2N2926, orange coded (G.E.)		
Q_3 =	2N3704	(Texas)	
D_1–D_2 =	1 A,	silicon rectifiers	
D_3–D_5 =	general purpose silicon diodes		
RLA =	12 V relay, coil resistance greater than 120 Ω, two sets of high current N/O contacts		
	Veroboard, hook-up wire, etc.		

constructional details on this panel. A photograph of the panel is shown in Plate 10.1.

When construction is complete, connect the panel up to the relay coil, and connect the supply leads across a 12 V battery and check that the relay goes on and off correctly. The operating rate of the unit can be reduced, if required, by increasing the values of C_1 and C_2, or by increasing the values of R_5 and R_6 (by equal amounts), up to a maximum value of 120 kΩ.

When the flasher unit is operating correctly it can be installed in the vehicle, together with RLA–S_3–D_1–D_2–R_1 and R_2, to conform to

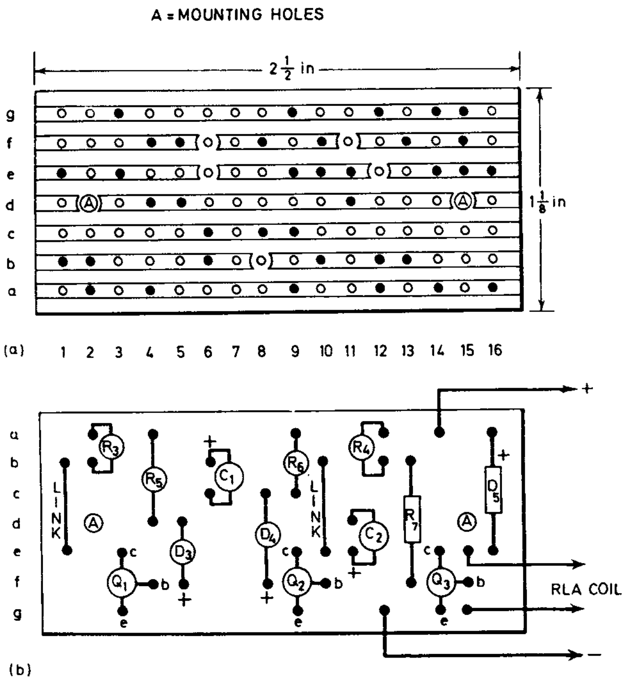

Fig. 10.4. Veroboard arrangement
(a) Copper side
(b) Component assembly on plain side

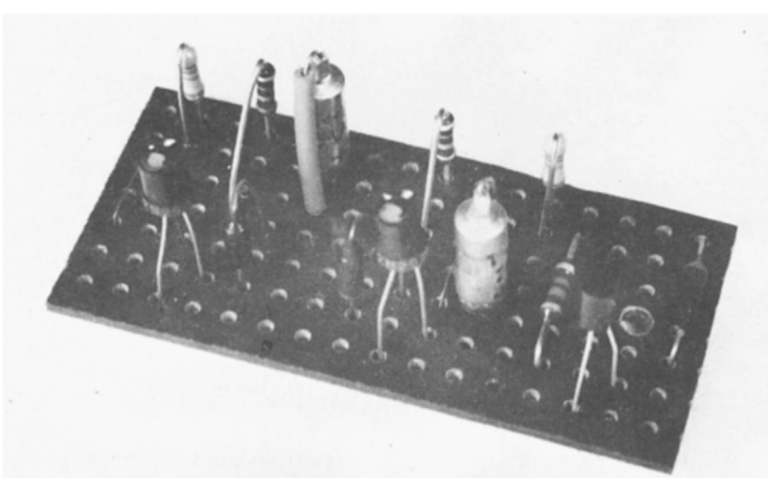

Plate 10.1

Fig. 10.2a or 10.2b (depending on the type of electrical system fitted in the vehicle in question). When the installation is complete, close S_3 and check that all four lamps flash on and off together, as described. Next, turn S_3 off and switch the car's ignition *on*, then check that the flashing turn indicators still operate normally; if all four lamps operate together under this condition, it is probable that D_1 or D_2 is defective, and the faulty component must be replaced. The unit is then complete and ready for use.

When using the system, note that if the emergency flasher and the turn-indicator flasher systems are both turned on together, only the emergency system will in fact operate; this is because the pre-heating of the lamps by the emergency system upsets the operation of the electro-mechanical turn-indicating flasher unit. If the emergency system is inadvertently left on when the car is in use, therefore, the error will become self-evident as soon as the turn-indicator switch is operated.

A panel warning light can, if required, be wired across the electronic flasher unit, so that it indicates when the emergency flasher system is in use.

Project 11

LIGHTING-FAULT INDICATOR

This unit monitors the car's lighting system and operates a dash-panel warning lamp if any of the tail, side, brake, or license-plate lamps burn out. The project is a particularly worth-while one, and comes into the 'life saving' class. Remember, thousands of people are killed each year in night-driving accidents caused by defective tail, side and stop lamps. These types of accident can often be avoided with the aid of the lighting-fault indicator described here.

Basic principles of operation

The basic principle of a +ve ground lamp-failure indicator is illustrated in Fig. 11.1a. Circuit operation relies on the fact that the forward voltage developed across a heavily conducting silicon diode (D_1 or D_2) is typically about 900 mV, while the base-emitter voltage needed to turn on a silicon transistor (Q_1 or Q_2) is only about 650 mV.

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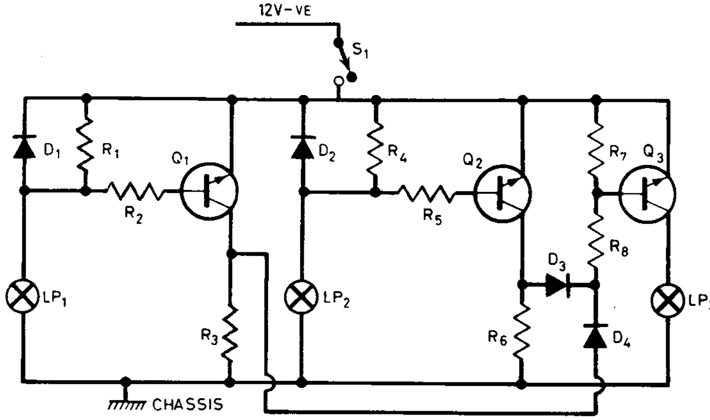

Fig. 11.1a. Basic lamp failure indicator, +ve ground version

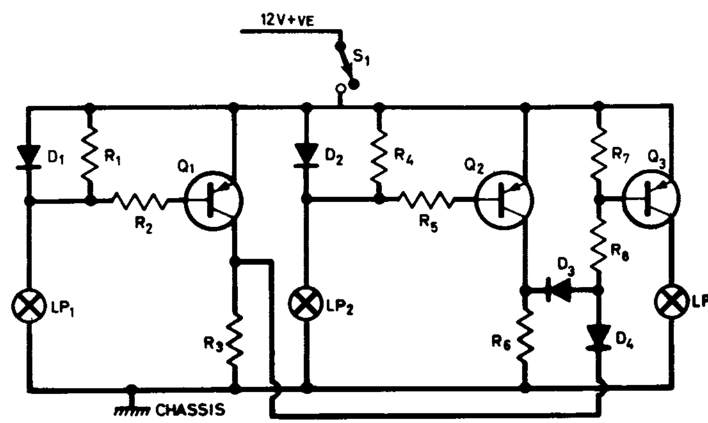

Fig. 11.1b. Basic lamp failure indicator, –ve ground version

Suppose that LP_1 and LP_2 are in good order, and S_1 is closed. Current flows through LP_1 via D_1, and through LP_2 via D_2, and both lamps are on. A forward voltage of about 900 mV is developed across D_1, and is applied to Q_1 base via R_2, so Q_1 is driven to saturation and its collector goes to 12 V –ve. Similarly, the D_2 forward voltage drives Q_2 to saturation, and its collector goes to 12 V –ve.

The collectors of Q_1 and Q_2 are coupled to the base of Q_3 via D_4 and D_3 and R_8, and Q_3 has a dash-panel warning lamp, LP_3, wired in series with its collector. Now, Q_3 and LP_3 are driven on only when substantial Q_3 base current flows to the ground line; since the collectors

of both Q_1 and Q_2 are at 12 V –ve under the above condition, therefore, zero current is applied to Q_3 base, so LP_3 is off, indicating that both LP_1 and LP_2 are working correctly.

Suppose, on the other hand, that LP_1 has burnt out. No current flows through D_1, so no forward voltage is developed across it. Q_1 is therefore held cut off via R_1 and R_2, and zero Q_1-collector current flows through R_3; Q_3 base is therefore connected to ground via R_3, D_4, and R_8 under this condition, so Q_3 is driven to saturation and LP_3 goes on, indicating that LP_1 has burnt out. D_3 is reverse biased under this condition, so Q_2 collector potential is unaffected by the change in R_8 voltage. A similar action to the above is obtained if LP_2 burns out, i.e., LP_3 is automatically turned on. Thus, LP_3 is normally off, but goes on if LP_1 or LP_2 burns out.

Note that the circuit uses fairly simple logic techniques; Q_1 and Q_2 are used as inverter switches, and are either full on or full off. Q_3 acts as a switch that is operated in the OR logic mode by gate diodes D_3 and D_4. The system can be expanded to operate from any number of lamps by simply wiring a D_1–R_1–R_2–Q_1–R_3 circuit to each lamp and connecting its Q_1 collector to R_8 via a gate diode such as D_4. R_8 keeps the base current of Q_3 within safe limits in the event of more than one lamp burning out.

Fig. 11.1b shows the basic –ve ground version of the unit. This is similar to the above, except that the polarities of all diodes are reversed and that all npn transistors are replaced with pnp types.

Practical systems

A typical car lighting system is shown in simplified form in Fig. 11.2. Flasher and brake light systems are inoperative until the ignition switch is closed. Note that there are a total of six main circuits in the system, and a total of sixteen lamps, as follows.

Headlamps (dipped) circuit	$= LP_1 – LP_2$.
Headlamps (main) circuit	$= LP_3 – LP_4$.
Parking light circuit	$= LP_5 – LP_{10}$.
Brake light circuit	$= LP_{11} – LP_{12}$.
Flasher (left) circuit	$= LP_{13} – LP_{14}$.
Flasher (right) circuit	$= LP_{15} – LP_{16}$.

Some cars may have additional circuits and lamps, i.e., reverse lights, etc., and some may have fewer lamps than shown, i.e., only one license plate lamp, etc. In all cases, however, lighting diagrams are roughly similar to that shown.

Not all of these lamps need to be monitored by a practical lighting-fault indicator. There is, for example, no need to monitor the headlights, because their beams can be seen from the driver's seat, and the

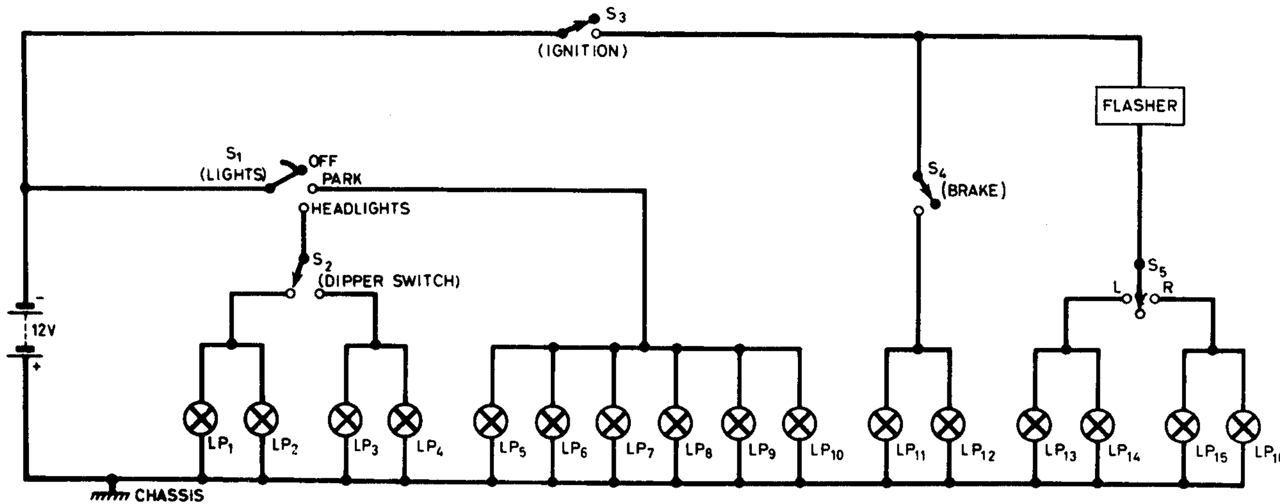

Fig. 11.2. Simplified diagram of typical car lighting system

LP_1	=	L.H. headlight, dipped
LP_2	=	R.H. headlight, dipped
LP_3	=	L.H. headlight, main
LP_4	=	R.H. headlight, main
LP_5	=	L.H. side park light
LP_6	=	R.H. side park light
LP_7	=	L.H. tail light
LP_8	=	R.H. tail light
LP_9	=	License plate light
LP_{10}	=	License plate light
LP_{11}	=	L.H. brake light
LP_{12}	=	R.H. brake light
LP_{13}	=	L.H. flasher (front)
LP_{14}	=	L.H. flasher (tail)
LP_{15}	=	R.H. flasher (front)
LP_{16}	=	R.H. flasher (tail)

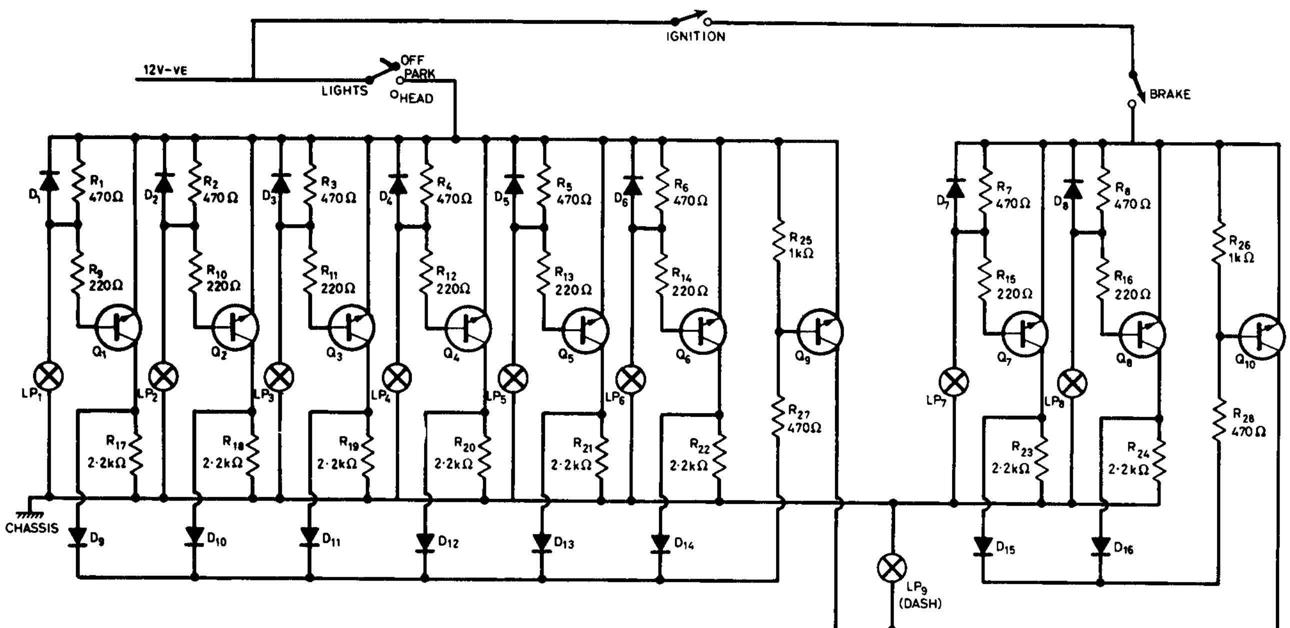

Fig. 11.3. Circuit of practical lighting-fault indicator, +ve ground version (see text for −ve ground version)

Components list (Fig. 11.3)

$D_1 - D_8$	=	silicon rectifiers (see text)
$D_9 - D_{16}$	=	general purpose silicon diodes
$Q_1 - Q_8$	=	low power silicon npn Transistors, $h_{FE} > 20$ (see text)
$Q_9 - Q_{10}$	=	medium power silicon transistors, npn, $h_{FE} > 50$, I_c (max) > 300 mA
$R_1 - R_8$	=	470 Ω, ⅛ W
$R_9 - R_{16}$	=	220 Ω, ⅛ W
$R_{17} - R_{24}$	=	2.2 kΩ, ⅛ W
$R_{25} - R_{26}$	=	1 kΩ, ⅛ W
$R_{27} - R_{28}$	=	470 Ω, ⅛ W

LP_1	=	L.H. side park light
LP_2	=	R.H. side park light
LP_3	=	L.H. tail light
LP_4	=	R.H. tail light
LP_5	=	license plate light
LP_6	=	license plate light
LP_7	=	L.H. brake light
LP_8	=	R.H. brake light
LP_9	=	12 V dash panel light, 40–100 mA type

driver will usually be aware of a lamp failure as soon as it occurs. Again, most cars are fitted with flasher units of the bimetal type, in which the flasher lamps are used as ballast resistors in series with the bimetal element; in this type of unit, both flasher lamps (LP_{13}–LP_{14} or LP_{15}–LP_{16}) must be in good order if the unit is to work; if one lamp burns out, insufficient current flows through the bimetal strip to cause correct heating of the strip, so the flasher ceases to work at all; the flasher circuit is thus self-monitoring, and there is thus no need to monitor the flasher light via the lighting-fault indicator.

Thus, the only lights that really need to be monitored by the lighting-fault indicator are the parking lights (LP_5–LP_{10}) and the brake lights (LP_{11}–LP_{12}), i.e., a practical system needs to monitor only two circuits and a total of eight lamps. Fig. 11.3 shows the full circuit needed to monitor these light in a +ve ground system. In spite of its apparent complexity, the circuit is really very simple, since it actually comprises only two basic circuits and a lot of duplication.

Each lamp in the system is wired to a simple D_1–R_1–R_9–Q_1–R_{17}–D_9 type of inverting 'switch', which forms one of the two basic circuits. The second type of basic circuit is the R_{25}–R_{27}–Q_9 gate section, which drives the LP_9 dash-panel lamp. There is one of these gate sections to each of the two main lighting circuits in the system (parking lights and brake lights). Thus, if you wish to monitor more (or fewer) lamps or main-lighting circuits in your particular car, you simply add (or take away) an inverting 'switch' for each lamp, and a gate section for each main-lighting circuit.

Semiconductor types are not critical in this circuit, and low-cost 'bargain' types can be used with safety. The following is a guide to component requirements.

D_1–D_8: These are silicon rectifiers. Most car lamps (other than head lamps) have wattage ratings between 6 and 36 W, so in a 12 V system operating currents are between 0.5 and 3 A. Thus, in most cases these rectifiers can be low-voltage 3 A types. Check lamp wattages before selecting these components, and increase the current ratings of the rectifiers if necessary.

Q_1–Q_8: These can be almost any low power npn silicon transistors with current gains greater than 20; check, however, that these transistors will switch hard on (saturate) with emitter-base voltages of less than 700 mV, and that at least 900 mV is developed across each D_1-type rectifier under operating conditions. (A differential voltage of at least 200 mV is needed for correct circuit operation.)

Q_9–Q_{10}: Any medium power silicon npn transistors with current gains greater than 50 and I_c (max) ratings of 300 mA or greater.

D_9–D_{16}: Any general purpose silicon diodes.

The –ve ground version of the circuit, and its component requirements, are very similar to those of Fig. 11.3, except that the

polarities of all rectifiers and diodes are reversed, and all npn transistors are replaced by pnp types.

In use, the dash-panel warning lamp, LP_9, goes on only when a light fails to come on when it is supposed to. In other words, if you have a burned-out tail lamp, the dash light will not indicate the fault until the parking light switch is turned on. The two main lighting circuits operate independently, i.e., if a brake light is burned out, the fault will show up on the warning lamp as soon as the brake pedal is pressed (assuming that the ignition is turned on), even if the parking light switch is not turned on at the same time.

Construction and use

Constructional details of the unit are in no way critical, and are best varied to suit individual needs; constructional details are not, therefore, given here. On the prototype, however, the circuit is split into two parts, the monitors for LP_1 and LP_2 being mounted under the dash panel, and the monitors for the remaining lamps being mounted in the rear luggage compartment. Rectifiers D_1–D_8 are mounted on metal heat sinks, to prevent overheating.

Before starting construction, check that the circuit of Fig. 11.3 is suitable for use in a particular car, and modify the circuit if necessary, i.e., change semiconductor polarities in the case of a –ve ground vehicle, and add or remove circuit sections as required. Check that the car is fitted with a self-monitoring flasher unit; to do this, set the flasher to operate normally to (say) the left, then remove one of the left hand (front or rear) flasher lamps; if the flasher is of the self-monitoring type, it will then cease to operate. If the flasher is not of the self-monitoring type, add more sections to Fig. 11.3 so that all flasher lamps are monitored.

It is strongly recommended that the finished unit be used in conjunction with the panel light flasher of Project 6; this is accomplished by wiring the common Q_9–Q_{10} collector connection of Fig. 11.3 to one of the input terminals of Project 6.

Project 12

TWO-LEVEL BRAKE LIGHTS

This simple little unit enables the car's brake lights to operate normally in daylight, but causes them to operate at reduced brightness under

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Project 12

TWO-LEVEL BRAKE LIGHTS

This simple little unit enables the car's brake lights to operate normally in daylight, but causes them to operate at reduced brightness under

night driving conditions, thus eliminating the danger of dazzling following drivers. The circuit uses only one relay and one or two resistors, and although not really 'solid-state' is felt to be well worth including in this volume.

How it works

Fig. 12.1 shows the basic version of the unit. Low value resistor R_1 is wired in series with brake lights LP_1 and LP_2, and is shunted by

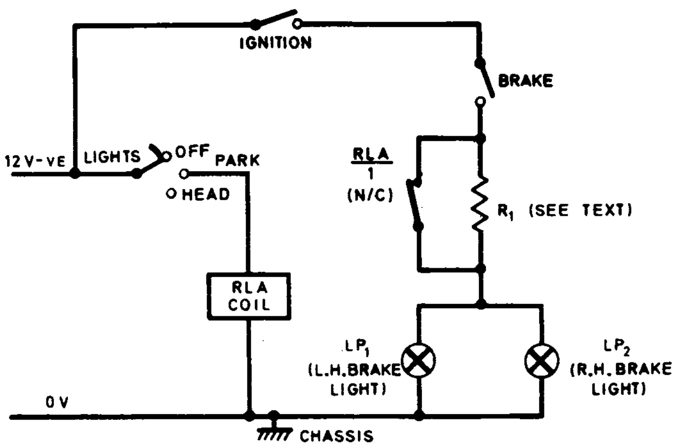

Fig. 12.1. Basic version of two-level brake light circuit (+ve ground)

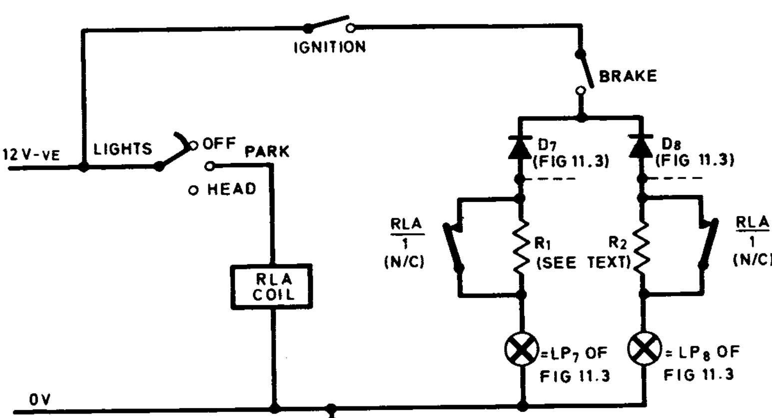

Fig. 12.2. Modification needed if the unit is to be used in conjunction with the lighting-fault indicator of Fig. 11.3

normally-closed (N/C) relay contact *RLA/1*. The coil of relay *RLA* is wired across the vehicle's parking light circuit.

Thus, under daylight driving conditions the parking lights and the relay are off, so R_1 is shorted out and the brake lights operate at full brilliance. Under night driving conditions, on the other hand, the parking lights, and thus the relay, are turned on, so contact *RLA/1* is open; R_1 is thus in series with the brake lights under this condition, so LP_1 and LP_2 operate at reduced brilliance.

The value of R_1 can be varied, by trial and error, to suit individual requirements. Good results are, however, given if R_1 is given a value equal to one quarter of the hot resistance of LP_1 or LP_2, and a power rating equal to LP_1 or LP_2; i.e., if the lamps are 12 V 21 W types, (giving a hot resistance of about 7 Ω), R_1 should have a value of about 1.75 Ω at 21 W. Relay *RLA* can be any 12 V type with one or more N/C contacts of suitable rating.

If the unit is to be used in conjunction with the lighting-fault indicator of Project 11, it must be modified as shown in Fig. 12.2. In this case a resistor (R_1 or R_2) is wired in series with each individual brake light, and a relay with two sets of N/C contacts is used. R_1 and R_2 should in this case each have values equal to half of LP_1 or LP_2 hot resistance, and a power rating equal to half of that of LP_1 or LP_2.

Project 13

LIGHTING SLAVE

This unit operates the car's lights automatically; when the car is in use it automatically turns the lights on at dusk and off at dawn; it turns them off automatically when the vehicle is parked: When the car is parked, the unit can, however, be made to function as an automatic parking light operator, if required, by turning the ignition switch to the *Acc* position. The device thus eliminates the need to operate the standard light switch manually.

The unit gives an outstandingly good performance. It uses four transistors, and utilizes dual-time-constant light-level integrating techniques, combined with precision triggering with controlled backlash. It turns the car lights on if the light level falls briefly below a pre-set value, but only turns them off again if the light level fails to fall momentarily below that level again within the following 30 seconds or so; it is unaffected by sudden increases in light level, such as are caused

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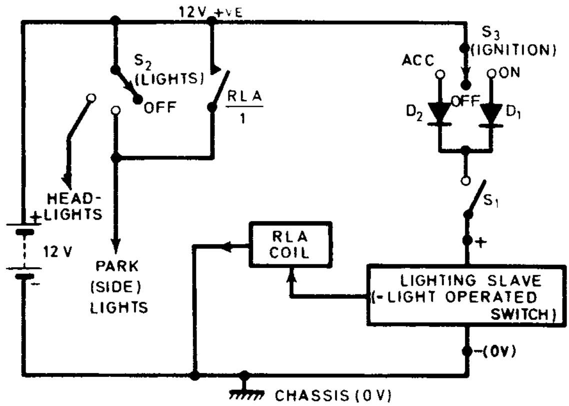


Fig. 13.1a. Method of connecting lighting slave in –ve ground vehicles

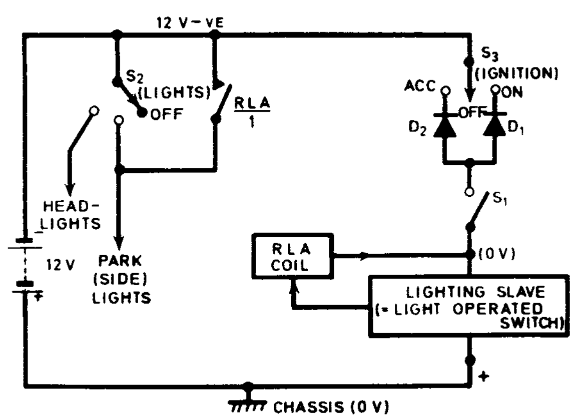


Fig. 13.1b. Method of connecting lighting slave in +ve ground vehicles

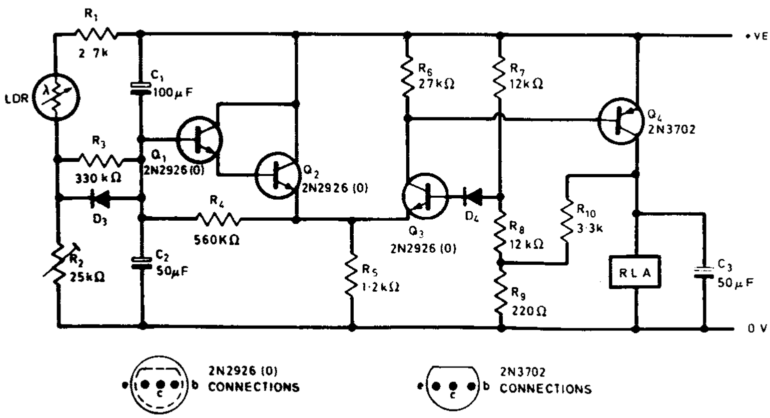


Fig. 13.2. Circuit and transistor connections of the lighting slave

Components list (Figs. 13.1 and 13.2)

R_1	=	2.7 kΩ,	¼ W	
R_2	=	25 kΩ,	skeleton pre-set, vertical mounting	
R_3	=	330 kΩ,	¼ W	
R_4	=	560 kΩ,	¼ W	
R_5	=	1.2 kΩ,	¼ W	
R_6	=	27 kΩ,	¼ W	
R_7	=	12 kΩ,	¼ W	
R_8	=	12 kΩ,	¼ W	
R_9	=	220 Ω,	¼ W	
R_{10}	=	3.3 kΩ,	¼ W	
C_1	=	100 μF,	12 V	electrolytic
C_2	=	50 μF,	12 V	electrolytic
C_3	=	50 μF,	15 V	electrolytic
S_1	=	on/off switch		
Q_1–Q_3	=	2N2926, orange coded (G.E.)		
Q_4	=	2N3702 (Texas)		
D_1–D_4	=	general purpose silicon diodes		
RLA	=	12 V relay, coil resistance greater than 120 Ω, one set of N/O contacts		
LDR	=	cadmium sulphide photocell, ¼ to ½ in face diameter, resistance = approx. 2 kΩ to 5 kΩ at 100 lux i.e., type TPMD–6LS by Sanken (Japan) or similar		

Veroboard, hook-up wire, etc.

by lightning flashes or street lights. Consequently, the car lights are operated without the slightest sign of flicker, even on the verge of dusk or dawn.

How it works

The lighting slave operates basically as a relay-driving light-sensitive 'switch', and Fig. 13.1a shows how it is connected in –ve ground vehicles to give automatic operation of the lights. Power is connected to the lighting slave and relay via normally closed switch S_1 and via D_1 or D_2 and the vehicles *ignition* switch. Normally-open relay contact *RLA/1* is wired between the 12 V +ve line and the *park* terminal of *lights* switch S_2.

Assume that the car is in use; S_3 is thus turned *on*, and power is applied to the lighting slave via D_1 and S_1: If it is dark, the slave automatically drives the relay on and closes contact *RLA/1*, thus turning the car's park or side lights *on*; if, on the other hand, it is not dark, *RLA* is not driven on, so contact *RLA/1* stays open and the lights are *off*. Similarly, if S_3 is moved to the *Acc* position power is applied to the lighting slave via D_2, and the unit turns the lights on automatically at night and off in the daytime; the slave thus acts as an automatic parking light operator. Finally, when the car is parked normally the *ignition* is naturally turned to the *off* position, and in this case power is removed from the slave and the lights are thus automatically turned off.

When S_3 is turned to the *on* position, D_2 is reverse biased and thus ensures that the supply does not appear at the *Acc* contacts; similarly, when S_3 is in the *Acc* position D_1 keeps power away from the *on* terminal.

Fig. 13.1b shows how the lighting slave is connected in +ve ground vehicles. In this case the polarities of D_1 and D_2 and the supply leads of the slave are reversed, but operation is otherwise the same as outlined above.

Fig. 13.2 shows the circuit of the actual lighting slave unit. The circuit is made up of four basic sections. These are (1) a light-to-voltage converter (R_1–*LDR*–R_2), (2) a dual-time-constant voltage integrating network (R_3–D_3–C_1–C_2), (3) a differential amplifier (Q_1–Q_2 and Q_3), and (4) a relay-driving regenerative switch (Q_3 and Q_4). Circuit theory is moderately complex, and to help simplify initial explanations we will for the moment merely assume that sections (1) and (2) work together to give a voltage on Q_1 base that is proportional to light level, and go straight on to look at the operation of sections (3) and (4), as follows.

Q_1–Q_2 and Q_3 are wired as a differential voltage comparator; a

fixed reference potential is applied to its Q_3 side via voltage divider R_7–R_8–R_9, and a variable input voltage is applied to the Q_1–Q_2 side via the (1) and (2) sections of the unit; Q_1 and Q_2 ensure that a very high input impedance is presented to the variable input voltage. The collector current of Q_3 is fed into the base of relay-driving transistor Q_4, and a positive feedback loop is wired from Q_4 collector to Q_3 base via R_{10}–R_9–R_8–D_4, so that Q_3 and Q_4 work together as a regenerative switch.

When the Q_1–Q_2 input voltage is more than a few tens of millivolts greater than the fixed reference voltage of Q_3, Q_1 and Q_2 are biased on and cause the emitter-base junction of Q_3 to be reverse biased, so Q_3 is cut off; zero base current thus flows in Q_4 under this condition, so Q_4 and the relay are off.

When, on the other hand, the Q_1–Q_2 input voltage falls to a value almost equal to that of Q_3, a point is reached where Q_3 just starts to turn on and Q_1–Q_2 are still conducting; as Q_3 starts to go on, its collector current is fed into the base of Q_4, and Q_4 starts to turn on also. As Q_4 starts to go on, a fraction of its rising collector voltage is fed back to Q_3 base via R_{10}, and turns Q_3 on even harder; a regenerative action thus takes place, and Q_3 and Q_4 are driven rapidly to saturation and the relay goes on. Once regeneration is complete, the Q_3 reference voltage is raised by a few hundred mV by the potential divider action of R_9–R_{10}, so Q_3 and Q_4 and the relay only turn off again when the Q_1 input voltage rises a fixed amount above the initial turn-on trigger voltage; R_9 and R_{10} thus give the trigger circuit a controlled degree of backlash.

Thus, Q_4 and the relay are off when a high voltage is applied to Q_1 base, but turn on rapidly as soon as the Q_1 voltage falls to a value equal to that of the fixed reference potential of Q_3; once Q_4 and the relay have turned on, they only turn off again when the Q_1 voltage rises a fixed amount above the initial Q_3 reference voltage.

D_4 is used to make the trigger levels independent of variations in circuit temperature, and C_3 prevents transients in the supply line from causing erratic triggering. Since Q_1–Q_2 and Q_3 are wired in the differential mode, variations in supply line potential effect both halves of the amplifier by equal amounts, and the circuits trigger levels are thus independent of supply line variations. The circuit thus gives exceptionally stable and precise voltage triggering. Having cleared up these details, we can now look at the details of the light-to-voltage converter (1) and differentiating (2) sections of the circuit, as follows.

LDR is a cadmium sulphide photocell, and acts as a resistance that decreases in value as light level increases. The *LDR* is wired as a potential divider with R_1 and R_2, so that the voltage on the *LDR*–R_2 junction increases with light level; the voltage is high under bright conditions, and low under dark conditions. This voltage is used to

charge capacitors C_1 and C_2 via R_3 and D_3, and these four components act together as a dual-time-constant differentiating network. The resulting differentiated voltage is applied directly to Q_1 base.

The action is such that if the light level on the face of the *LDR* suddenly increases, the voltage at the $LDR-R_2$ junction rises sharply above that of Q_1 base, and D_3 is reverse biased; C_1 and C_2 thus charge with a long time constant via R_3 under this condition. If, on the other hand, the light level suddenly falls, the voltage on the $LDR-R_2$ junction falls rapidly below that on Q_1 base, and D_3 is forward biased; C_1 and C_2 thus discharge with a short time constant via D_3 and R_2 under this condition. Thus, the Q_1 base voltage responds fairly rapidly to decreases in light level, but only very slowly to increases in light level.

R_4 is a bootstrapped resistor that helps compensate for leakage currents in C_1 and C_2, but has negligible shunting effect on the high input impedance of Q_1 base. C_1 and C_2 are wired as a potential divider across the supply line, so that Q_1 and Q_2 are not automatically driven off (and Q_3 and Q_4 and the relay driven on) when the supply is initially connected to the circuit.

When using the completed circuit, R_2 is adjusted so that, once Q_4 and the relay have been turned on, they only just turn off again when the light level is kept equal to that of dusk or dawn for about 30 seconds, i.e., so that the Q_1 and Q_3 input voltages are nearly equal under this condition. When the car is then used in near-dusk conditions, the relay goes on as soon as the vehicle enters a shadowed area in which the light level is below the mean dusk level; the circuit backlash then ensures that the relay only goes off again if the car is then kept in an area with above-dusk lighting for at least 30 seconds: Under practical driving conditions, these turn-off conditions are only met at dawn, so that in practice the relay goes on promptly at dusk, and only turns off again at dawn, the circuit being unaffected by normal transient light level variations in the meantime. Once the relay has turned off at dawn, it only turns on again if the light level falls momentarily a substantial amount below the mean dawn level, i.e., under the turn-on conditions mentioned above, or when driving under a tunnel or similar dark area in daytime. The unit thus gives very stable operation of the relay, with no sign of 'chatter'. If the car is driven under a dark tunnel in daytime, the relay is driven on almost at once, and then stays on until about 30 seconds after the car is driven into daylight again.

Construction and use

The major part of the circuit, less the relay but complete with D_1 and D_2, is wired up on a 3 x 1½ in piece of Veroboard panel with 0.15 in

hole spacing. Fig. 13.3 shows constructional details of the +ve ground version of the unit; the –ve ground version is identical, except that the polarities of D_1 and D_2 are reversed. When making up the circuit, do not connect the link between holes 10a and 10d until the unit has been tested as described later.

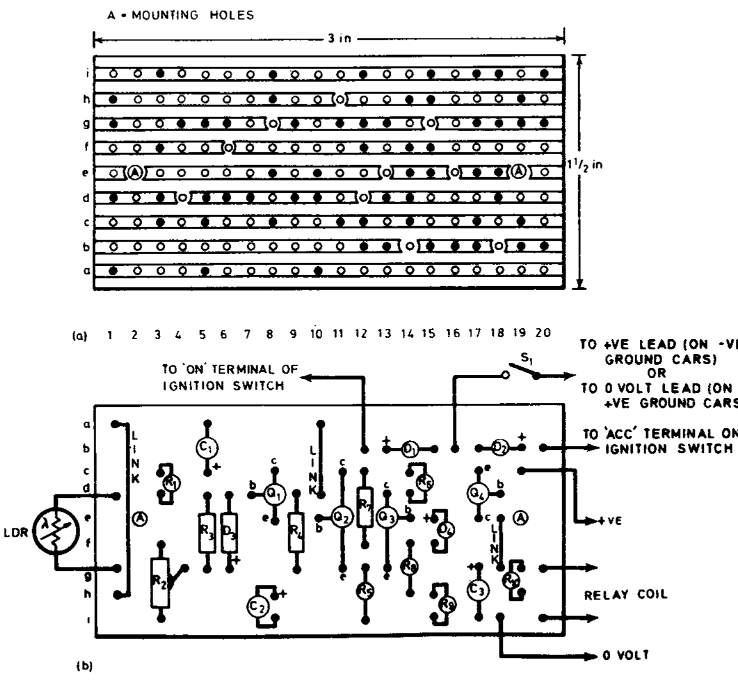


Fig. 13.3. Veroboard arrangement
(a) Copper side
(b) Component assembly on plain side, +ve ground version of unit
Note: –ve ground version is identical except that polarities of D_1 and D_2 are reversed

The actual *LDR* is mounted in a small 'head' and is connected to the circuit via a pair of flexible leads. The head itself is then bonded to the car's dash panel, with the *LDR* face looking into the vehicle. Fig. 13.4 shows how the prototype head was made.

Here, the *LDR* leads are first cut off short and their stumps are soldered to lengths of hearing aid flex; the wire stumps are then bent over at right angles to the *LDR* body. The *LDR* assembly is then bonded between a sandwich of plastic or wood; the upper half of the sandwich has a hole cut in it to clear the *LDR* body, and the lower half

is grooved so that the *LDR* leads can lay below its surface; when the two halves are bonded together they and the *LDR* form a solid block in which only the *LDR* face and leads are exposed. The head is then complete. A photograph of the completed panel and *LDR* head is shown in Plate 13.1.

When assembly of the electronic circuitry and the head is complete, instal them in the vehicle and test as follows.

Bond the *LDR* head to the car's dash panel, above the steering column, with the *LDR* face looking into the vehicle; connect the *LDR* leads and the relay coil to the main circuit. Connect D_1 and D_2 leads to the ignition switch, as shown in Figs. 13.1 and 13.3, and wire relay contact *RLA/1* across the cars *light* switch; on +ve ground cars, connect the 0 V lead of the unit to S_1, and the +ve lead to the car's chassis; on –ve ground vehicles, connect the +ve lead to S_1, and the 0 V lead to the chassis.

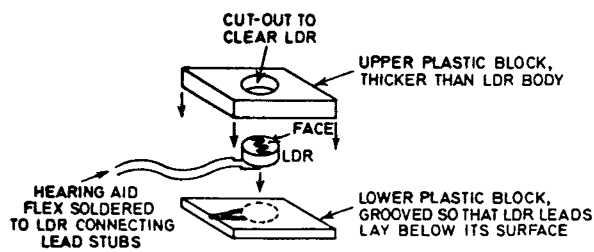


Fig. 13.4. Method of making prototype LDR head

Now, in daylight, with the wire link between holes 10a and 10d open, and with S_1 closed, turn the ignition *on*; shade the *LDR* face to what is estimated to be 'dusk' level of darkness, and adjust R_2 so that the relay and the car lights just go on; R_2 can, if necessary, be increased to a maximum value of 100 kΩ, so that the unit operates at the required darkness level. Now remove the shading from the *LDR* face, and check that the relay and car lights go off; make a note of the voltage developed across R_5 during this test. Next, check that the same action is obtained when the ignition is moved to the *Acc* position, and that the unit is inoperative when the ignition is turned *off*.

Now, again in daylight, wire in place the link between holes 10a and 10d; turn the ignition *on*, and again shade the face of the *LDR*; check that the relay operates, and that the voltage across R_5 is roughly the same as in the earlier tests; if the voltage is not roughly the same, it is probable that C_1 or C_2 is faulty, and the defective component must be replaced. Now remove the shading from the *LDR*, and check that the

relay goes off after 30 seconds or so; if it does not go off, even after a couple of minutes, try increasing the value of R_2 until the correct operation is obtained.

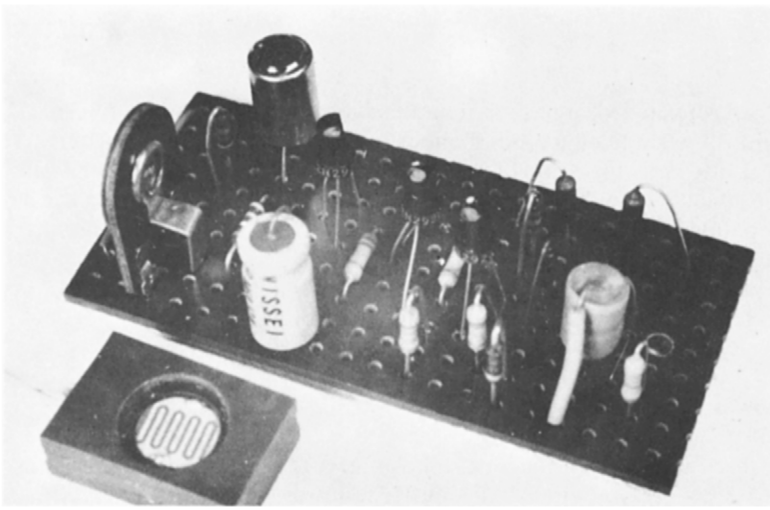


Plate 13.1

When the above tests are satisfactory, the unit can be finally adjusted as follows. Wait until just before the onset of dusk, and then shade the face of the *LDR* so that the relay goes on; remove the shading, and carefully adjust the value of R_2 so that the relay only just turns off again, after a delay of 30 seconds to a couple of minutes, at the onset of dusk (the larger the value of R_2, the darker are the conditions under which the relay turns off). Repeat this test a number of times, until the correct operation is obtained. The unit is then complete and ready for use.

Project 14

SPOTLIGHT TIME DELAY UNIT

When activated via a push switch, this unit turns a car's spot or head lights on for a fixed period of about two minutes. At the end of this period it turns the lights off again automatically. The unit thus enables the owner to use the vehicle lights to illuminate his passage along a drive or pathway after parking the car for the night, without fear of running down the car's battery.

The unit is simple to make and easy to instal in the vehicle. It is reasonably inexpensive to build, and compact in dimensions.

How it works

The full circuit of the unit is shown in Fig. 14.1. Circuit operation is very simple. Q_1 is wired as an emitter follower, with emitter load R_3, and has base bias provided via C_1. Q_2 is wired as a common emitter amplifier, using relay *RLA* as its collector load, and has its base bias provided from Q_1 emitter via R_3. Power is connected to the circuit via normally open (N/O) relay contact *RLA/1*, which is shunted by N/O push-button switch S_1. Circuit operation is initiated by briefly closing S_1.

When power is initially applied to the circuit via S_1, C_1 is fully discharged, so Q_1 base is effectively shorted to the 12 V +ve line via C_1. Q_1 emitter voltage 'follows' that on Q_1 base, so 12 V appears at Q_1 emitter, and Q_2 is driven fully on by the resulting high current of R_3; Q_2 thus turns the relay *on*. As the relay goes on, contact *RLA/1* closes, thus maintaining the +ve supply to the circuit after S_1 is opened, and contact *RLA/2* closes and turns the spot or head lights on. This action occurs almost instantly as S_1 is closed.

As soon as power is applied to the circuit, C_1 starts to charge slowly via the high input impedance of Q_1. As C_1 charges up, the Q_1 base and emitter voltages, and thus the base bias of Q_2, decay exponentially towards zero volts. Eventually, after a delay of about two minutes, the Q_1 emitter voltage decays to about 2 V, and insufficient base current then flows to Q_2 to hold the relay on. *RLA* thus turns off at this stage. As the relay switches off, contact *RLA/1* opens, breaking the supply to the circuit, and *RLA/2* opens, turning the spot or head lights *off*. Once the supply to the circuit is broken, C_1 discharges rapidly via D_1 and R_1, and the circuit is then ready for the next operation of S_1.

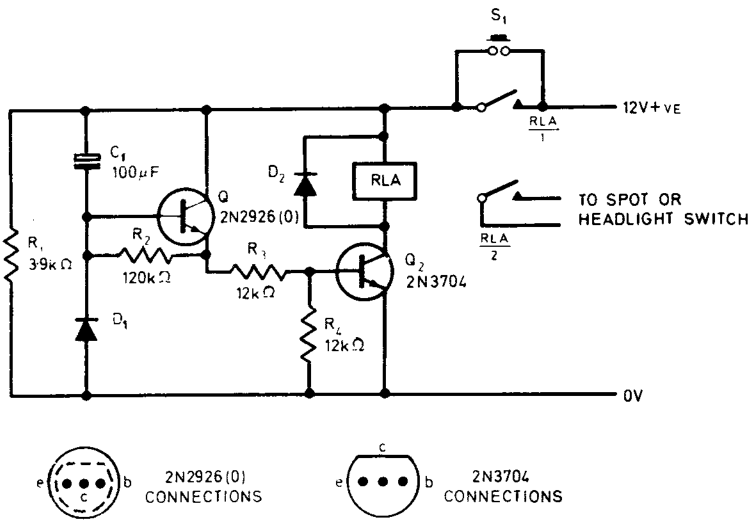


Fig. 14.1. Circuit and transistor connections of the time delay unit

Components list (Fig. 14.1)

R_1	=	3.9 kΩ,	¼ W	
R_2	=	120 kΩ,	¼ W	
R_3	=	12 kΩ,	¼ W	
R_4	=	12 kΩ,	¼ W	
C_1	=	100 μF,	25 V	electrolytic
RLA	=	12 V relay with 120 Ω or greater coil resistance; 2 sets of N/O contacts, one set with current rating to suit car's spot or headlights		
S_1	=	push-to-make switch		
Q_1	=	2N2926, orange coded (G.E.)		
Q_2	=	2N3704	(Texas)	
D_1	=	general purpose silicon diode		
		Veroboard, hook-up wire, etc.		

The time delay of the circuit is dictated primarily by the time constant formed by C_1 and the input impedance of Q_1; Q_1 must exhibit a high input impedance if long time delays are to be obtained. At the same time, however, Q_1 must exhibit a fairly low input resistance, otherwise the leakage currents of C_1 may upset the operation of the circuit. In Fig. 14.1 these conflicting circuit characteristics are provided via R_2. This component forms, together with R_3 and R_4, a resistive path of only about 140 kΩ between Q_1 base and the zero volts line, and thus provides considerable compensation for the steady leakage currents of C_1. As far as the varying exponential currents of C_1 are concerned, however, R_3 is 'bootstrapped' by the emitter follower

action of Q_1, and its impedance is thus raised to several megohms. Q_1 therefore exhibits the required high input impedance, and long time delays are available from the circuit.

Construction and use

The major part of the electronic circuitry is wired up on a $1\frac{7}{8} \times 1\frac{1}{8}$ in piece of Veroboard panel with 0.15 in hole spacing. Fig. 14.2 shows the component assembly details of the panel, and the associated wiring. A photograph of the completed panel is shown in Plate 14.1. Relay *RLA* can be any 12 V type with a coil resistance greater than 120 Ω and with two or more N/O contacts; one of these contacts must, however, have a current rating suitable for operating the car's spot or head lights.

When construction is complete, mount the panel and the relay in a suitable case; if a metal case is used, bond a couple of small rubber grommets to the underside of the panel, one below each mounting

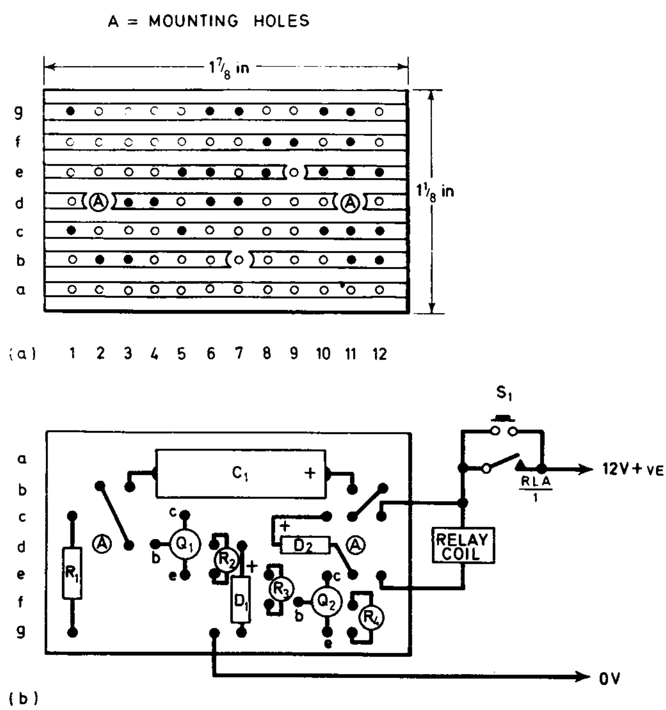


Fig. 14.2. Veroboard arrangement
(a) Copper side
(b) Component assembly and wiring details on plain side

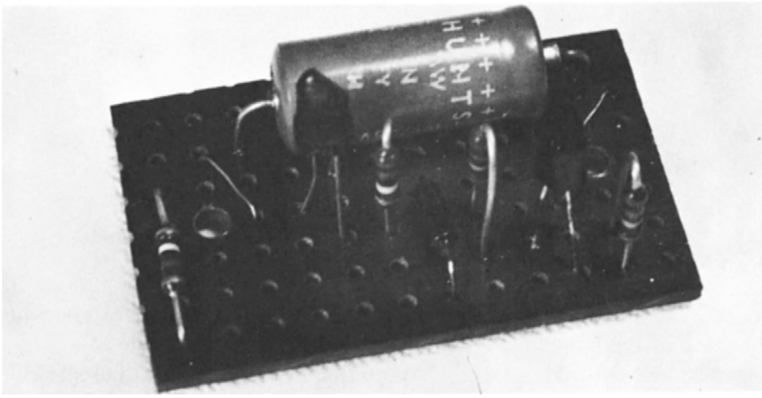


Plate 14.1

hole, to act as spacer/insulators to prevent the copper strips shorting to the case. The unit can now be given a simple functional test, as follows:

Connect the 12 V +ve lead, via *RLA/1* and S_1, to the +ve terminal of the car's battery, and connect the 0 volt lead to the –ve terminal. Connect relay contacts *RLA/2* across the spot light or headlight switch, as preferred. Now wire.a short across S_1 and check that the relay operates and that the lights come on. Next, connect a voltmeter between Q_1 emitter and the zero volt line, short a 1 kΩ resistor across D_1, and check that the relay and lights go off, and that the voltmeter reading falls to zero. Now disconnect the 1k resistor from across D_1, and check, over a period of about one minute, that the voltmeter reading does not rise above 0.5 V. If the voltage does rise above 0.5 V, C_1 has an excessively low leakage resistance, and must be replaced. Once this test is satisfactory, remove the short from S_1, then operate S_1 and check that the lights go on, and then turn off again automatically after a delay of roughly 2 minutes. If this last test is satisfactory, the unit can now be permanently wired in place in the vehicle.

The tested and installed unit can, if required, be simply wired directly to the car battery, as described above. A disadvantage of this connection is, however, that the unit can be inadvertently operated by accidently touching S_1, and that once the timing cycle has been initiated it can not be stopped manually.

These snags can be overcome by wiring the unit to the battery via the *Acc* terminal of the ignition switch (assuming that the vehicle has this facility). The unit can then only be operated by deliberately turning the ignition switch to the *Acc* position and then operating S_1, and once initiated the timing period can be ended prematurely, if required, by moving the ignition switch to the *off* position. This connection can be made in negative ground vehicles by wiring the unit's 12 V +ve lead to the *Acc* terminal of the ignition switch, and wiring the zero volt lead to ground. On positive ground vehicles it can be made by wiring the zero volt lead to the *Acc* terminal, and the 12 V +ve lead to ground.

Project 15

SUPPRESSED-ZERO VOLTMETER

A useful accessory in any car is a panel-mounted voltmeter for checking the state of the battery. Fig. 15.1 shows the circuit and scale of a conventional voltmeter used in this application. Note that the scale reads all the way from zero to 16 V. Now, the actual voltage of a car battery in good condition is nominally about 12.6 V, but may in practice vary between about 10 V and 16 V, depending on the state of the battery and its charging circuit; only the final $^3/_8$ths of the scale of the conventional voltmeter of Fig. 15.1 is thus of practical value, the remaining $^5/_8$ths serving no useful purpose.

Fig. 15.2 shows the circuit and scale of an alternative type of voltmeter, in which all voltages below 10 V are suppressed; the scale reads voltages in the range 10 to 16 V only; the full scale length of the meter is thus of practical value.

This type of instrument is known as a 'suppressed-zero' voltmeter, and its operating principle is very simple. Zener diode ZD_1 and multiplier resistor R_1 are wired in series with the 5 mA f.s.d. current meter; at voltages less than 10 V, therefore, ZD_1 is blocked, and zero current passes through the meter. At potentials above 10 V, on the other hand, ZD_1 conducts and has 10 V developed across it, the

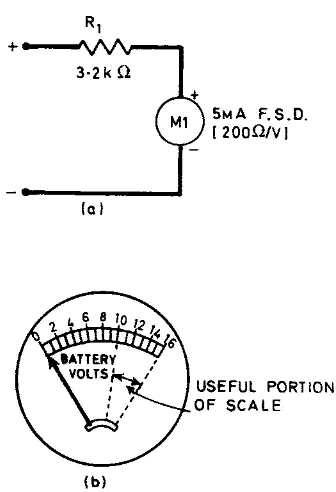


Fig. 15.1. Circuit and scale of conventional voltmeter

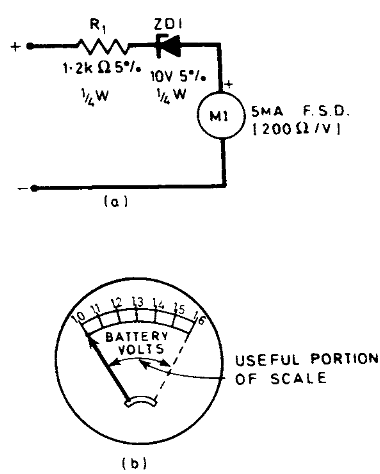


Fig. 15.2. Circuit and scale of suppressed-zero voltmeter

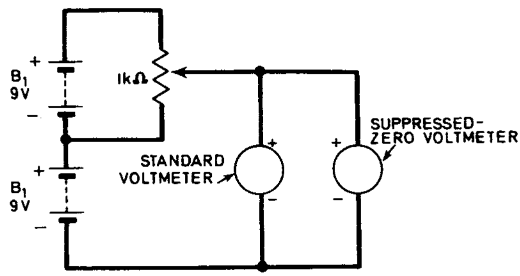


Fig. 15.3. Method of calibrating the suppressed-zero voltmeter

remaining voltage being developed across R_1; the current through M_1 is then equal to this remaining voltage divided by the R_1 value. A 5 mA f.s.d. meter has a basic sensitivity of 200 Ω/V, so R_1 is given a value of 6 x 200 Ω = 1.2 kΩ, to give a f.s.d. range of 6 V, i.e. a reading range of 10 to 16 V.

Construction and use

Construction of the unit is perfectly simple, and R_1 and ZD_1 can be wired directly to the meter terminals; take care to connect ZD_1 in the correct polarity. When construction is complete, the suppressed-zero voltmeter can be calibrated against a standard voltmeter using the circuit shown in Fig. 15.3. The old scale markings can be removed with a scraper or sharp knife, and the new ones put on with marking ink.

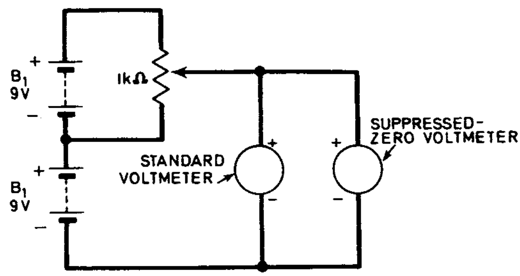
When construction is complete, instal the meter in the car and connect it to the vehicle's battery via the ignition switch, taking care to connect the meter leads in the correct polarity.

When using the meter, note that the 'correct' voltage of the battery is about 12.6 V. If battery readings are consistently less than 11 V, suspect a faulty battery cell; if readings are consistently in the range 11 to 12.5 V, suspect a faulty dynamo. Finally, if readings are consistently above about 14 V, suspect a defective voltage regulator.

Project 16

ANTI-SLEEP ALARM

This unit is a life-saving type of device; it automatically operates the car horns if the driver starts to relax excessively when driving, i.e., if he



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Project 16

ANTI-SLEEP ALARM

This unit is a life-saving type of device; it automatically operates the car horns if the driver starts to relax excessively when driving, i.e., if he

starts to fall asleep at the wheel. It thus instantly brings him back to a state of full alertness under this condition. The unit is of particular value when the vehicle is used on long night drives, or on tedious runs on motorways or autobahns, etc.

The operating principle of the device is quite simple, and is illustrated in Fig. 16.1. A metallic antenna is bonded to the rim of the steering wheel, and is coupled to a touch-sensitive relay-driving electronic switch via a slip-ring and pick-up brush; the relay contacts are wired across the vehicle's horn switch, and the unit is operational only when the ignition is turned *on* and S_3 is closed.

Suppose that S_3 is closed. When the car is driven normally, the driver has a firm hold of the steering wheel and the antenna; under this condition, the touch-sensitive electronic switch holds the relay and the car horns off. When, on the other hand, the driver starts to relax excessively (prior to falling asleep), his grip on the steering wheel and the antenna inevitably slackens; the touch-sensitive electronic switch senses this relaxation of grip, and responds by automatically driving the relay on and thus operates the car horns.

The design of the circuit is such that the horns operate only when *both* hands are relaxed at the same time; one hand can thus be safely removed from the steering wheel, to operate light switches, etc., without inadvertently operating the touch switch.

The electronic part of the circuit is moderately simple, and can be constructed without difficulty. Construction and fitting of the pick-up brush assembly and the slip-ring, on the other hand, present some mechanical problems, and the reader must be competent to tackle these problems if construction of the unit is contemplated.

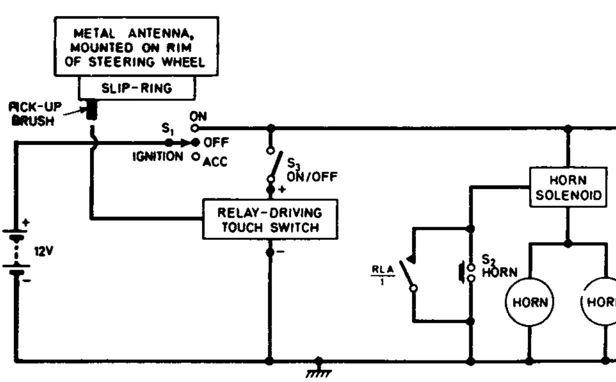


Fig. 16.1. Basic circuit of the anti-sleep alarm (–ve ground version)
Note: +ve ground version is identical, except that polarities of touch switch leads are reversed

How it works

Fig. 16.2 shows the full circuit of the relay-driving touch switch part of the unit. Q_1 is wired as a simple Colpitts oscillator, with gain adjustable via R_4, and the antenna is coupled to the oscillator tuned circuit via C_5. The output of this oscillator, which operates at about 300 kHz, is made available at a low impedance level across R_5 via emitter follower Q_2. This low impedance signal is rectified and smoothed via the D_1–D_2–R_7–C_7 network, to produce a positive bias that is fed to Q_3 base via R_8. Q_3 and Q_4 are wired as common emitter amplifiers; the collector current of Q_3 is fed into Q_4 base via R_{10}, and Q_4 drives relay *RLA*.

Now, when the unit is in use, R_4 is adjusted so that the oscillations of Q_1 are only just sustained when the antenna is not loaded externally. Consequently, when the steering-wheel-mounted antenna is held firmly, as it is under normal driving conditions, the driver's grip causes such additional capacitive loading of Q_1 tuned circuit that Q_1 ceases to oscillate; zero output is then available at Q_2 emitter, so zero bias is developed on Q_3 base, and Q_3–Q_4 and the relay and the car horns are therefore off under this condition.

When, on the other hand, the driver's grip on the antenna is severely relaxed or removed, the extra antenna loading falls to such a low value that Q_1 starts to oscillate normally. An a.c. signal is thus developed at Q_2 emitter under this condition, and this signal is rectified and smoothed via D_1–D_2–R_7–C_7 and drives Q_3 and Q_4 on. The car horns are thus operated via relay contacts *RLA/1* under this condition, alerting the driver to his excessively relaxed state.

It should be noted that, although this circuit has been described here as a 'touch-sensitive' switch, it is in fact a proximity detector that works on a capacitive loading principle. Operation is not dependent on a *resistive* contact between the driver's hands and the antenna, but on the capacitive loading caused by effectively connecting him between the antenna and 'ground', i.e., the car body. For correct operation, one side of the unit's supply must therefore be taken to the car chassis; the driver's body is, of course, effectively grounded capacitively by its sheer mass, and does not need to be grounded resistively. To ensure that the sensitivity of the circuit is unaffected by variations in battery voltage, the supply to the Q_1 oscillator stage is stabilized by zener diode ZD_1.

Construction and use

The relay-driving touch switch part of the unit is wired up, less the relay, on a 3¼ x 1⅛ in piece of Veroboard panel with 0.15 in hole

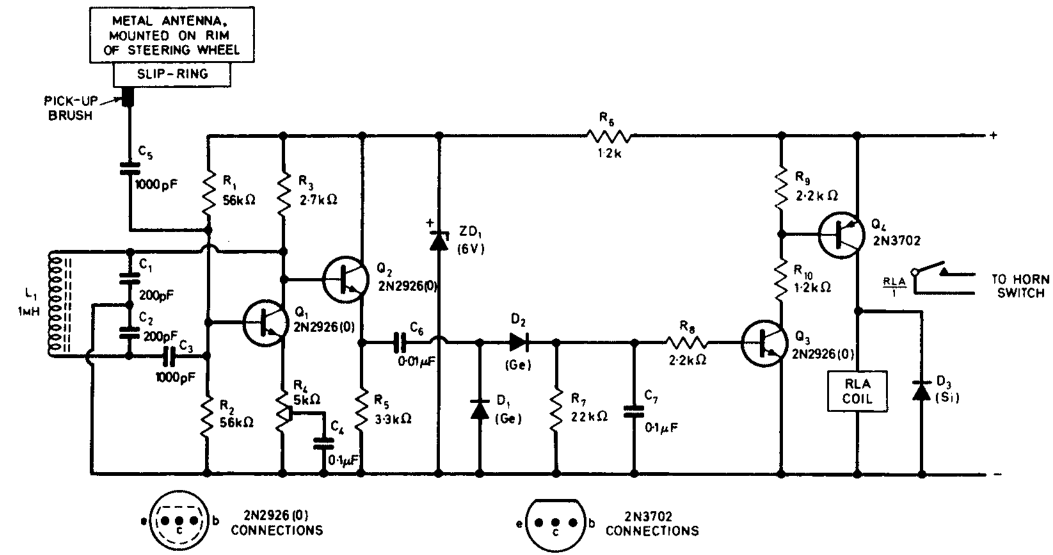


Fig. 16.2. Circuit and transistor connections of the relay-driving touch switch

Components list (Fig. 16.2)

R_1	=	56 kΩ,	¼ W
R_2	=	56 kΩ,	¼ W
R_3	=	2.7 kΩ,	¼ W
R_4	=	5 kΩ,	skeleton pre-set, vertical mounting
R_5	=	3.3 kΩ,	¼ W
R_6	=	1.2 kΩ,	¼ W
R_7	=	22 kΩ,	¼ W
R_8	=	2.2 kΩ,	¼ W
R_9	=	2.2 kΩ,	¼ W
R_{10}	=	1.2 kΩ,	¼ W
L_1	=	1 mH r.f. choke on ferrite former	
RLA	=	12 V relay with coil resistance greater than 120 Ω, and with one set of N/O contacts	
S_3	=	on/off switch	
C_1	=	200 pF silver mica	
C_2	=	200 pF silver mica	
C_3	=	1 000 pF,	Mylar
C_4	=	0.1 μF,	Mylar
C_5	=	1 000 pF,	Mylar
C_6	=	0.01 μF,	Mylar
C_7	=	0.1 μF,	Mylar
Q_1–Q_3	=	2N2926, orange coded (G.E.)	
Q_4	=	2N3702 (Texas)	
D_1–D_2	=	general purpose germanium diodes	
D_3	=	general purpose silicon diode	
ZD_1	=	any 6 V zener diode	
		Veroboard, hook-up wire, 5 feet of 'Cir-Kit' (⅛ in width) etc.	

spacing. Fig. 16.3 shows full constructional details of the circuit, and a photograph is shown in Plate 16.1.

When construction is complete, give the unit a functional test, as follows. Solder a 6 in piece of insulated wire in antenna hole 1a, and bare ¼ in of its free end; wire the relay in place, adjust R_4 slider down to the –ve supply rail, and then connect the unit's supply leads across a 12 V battery. Relay *RLA* should be off under this condition. Now carefully advance R_4 slider towards Q_1 emitter until a point is reached where the relay just turns on positively; now place one hand across the +ve or –ve terminal of the battery, and grip the bare end of the antenna wire with the other hand; the relay should turn off under this condition. The relay should turn on again when the hand is removed from the antenna wire. By carefully adjusting R_4, it should be possible to set the unit so that the relay goes off only when the antenna is gripped very firmly, or when it is gripped lightly, or when it is barely touched, as required.

The true proximity-detecting nature of the unit can, if desired, be demonstrated at this stage by connecting the antenna to a metal plate

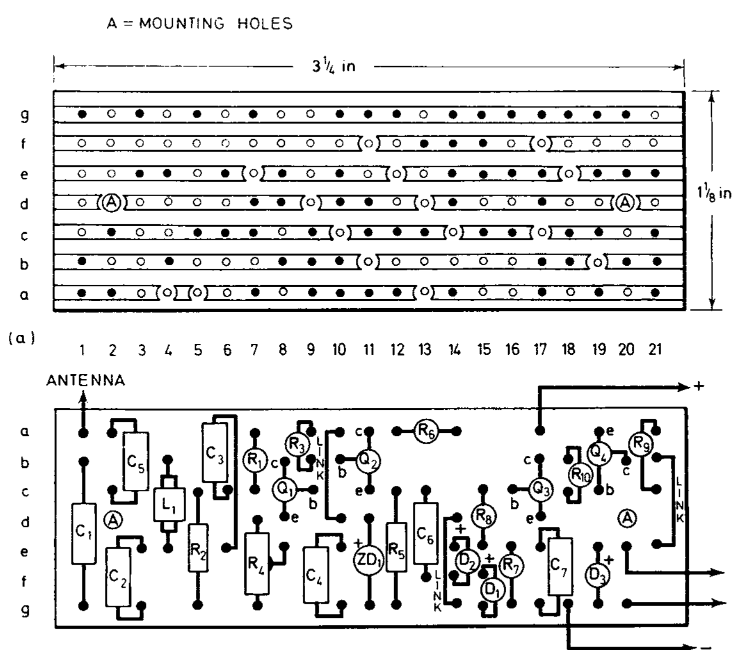


Fig. 16.3. Constructional details of the relay-driving touch switch on Veroboard
(a) Copper side
(b) Component assembly on plain side
Note: All shorting links (3 off) to be covered by insulating sleeving

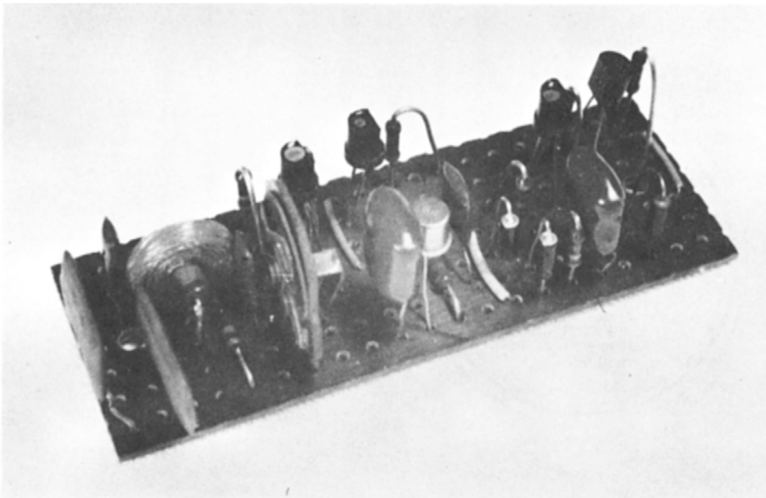


Plate 16.1

with a surface area of at least several square inches; by adjusting R_4 it should be possible to set the unit so that the relay is normally on, but goes off if one hand is merely placed within an inch or two of the metal plate, the other hand being taken to one of the battery terminals.

Once the touch switch has been tested as described above, it is ready for installation in the vehicle. The antenna assembly can now be made up, together with the slip-ring and pick-up brush units. The idea here is to bond a thin copper-strip 'antenna' to the inside rear of the steering wheel rim, in such a position that it is contacted by the hands only when the steering wheel is firmly gripped; one end of this antenna is then connected electrically to a brass slip-ring mounted on the steering wheel boss, near the steering column; a spring-loaded copper pick-up brush and metal holder is then mounted on the steering column cowling, so that the copper brush is in contact with the brass slip-ring, and the metal pick-up brush holder is wired to the antenna lead of the Veroboard circuit, so that a conductive path exists between the steering wheel antenna and the antenna lead of the Veroboard circuit in all positions of the steering wheel. The steering wheel and steering column cowling must, of course, be made of non-conductive material.

Construction of the antenna and pick-up assembly is rather difficult and time consuming, and on the prototype took over 20 hours to complete. Fig. 16.4 shows the method of construction used on the prototype; details may be varied to suit individual vehicles. The general procedure for making the assembly is as follows.

(1) Remove the steering wheel from the vehicle.

(2) Thoroughly clean the steering wheel, and use sandpaper to smoothly remove all paint from the inside rear of the rim.

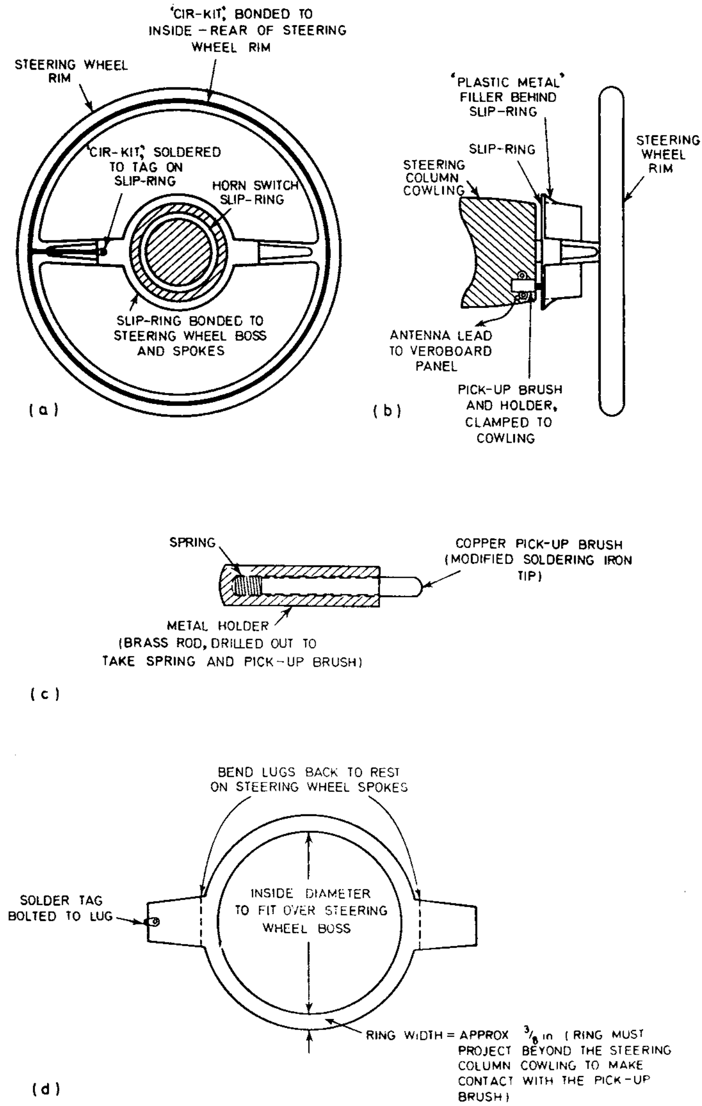


Fig. 16.4a. *Rear view of steering wheel assembly. ('Cir-Kit' antenna is shown at rear of rim for clarity, but in practice must be positioned further inside the rim)*

Fig. 16.4b. *Side view of steering wheel and column cowling*

Fig. 16.4c. *Method of making pick-up brush and holder (sectional view)*

Fig. 16.4d. *Slip-ring details (material, heavy brass sheet)*

(3) Make up a slip-ring from heavy brass sheet, as shown in Fig. 16.4d, and bend back the two (or more) lugs so that they fit the shape of the steering wheel spokes. Bolt a solder tag to one of the lugs.

(4) Bond the slip-ring in place on the steering wheel boss, as shown in Figs. 16.4a and 16.4b, using impact adhesive between the steering wheel spokes and the rear of the slip-ring lugs.

(5) Mould 'plastic metal', epoxy resin, or a similar 'filler' material between the rear of the slip-ring and the steering wheel boss, and carefully file and sandpaper the material so that the ring blends smoothly into the shape of the boss.

(6) The antenna can now be made up, using a 5 foot length of ⅛ in wide 'Cir-Kit' or a similar product; this is a fine copper strip, approximately 0.002 in thick, and has a powerful impact adhesive bonded to one side; the adhesive is normally covered with a protective backing paper. Fix the antenna in place as follows.

Remove the backing paper from one end of the strip, and solder the end to the solder tag on the brass slip ring. Now run the strip along one spoke, and then around the inside-rear of the steering wheel rim, as shown in Fig. 16.4a, in such a position that it will be contacted by the hands only when the wheel is gripped reasonably firmly; as the strip is run into place, remove the backing paper and firmly bond the strip to the wheel, burnishing the copper with the smooth shank of a drill or similar object so that all kinks are removed. Finally, remove all rough edges from the strip with fine sandpaper.

(7) At this stage, the antenna stands slightly proud of the surface of the steering wheel rim. To overcome this, paint over the area of the antenna with liquid cellulose filler (as used in repairing scratches in car paint), and then, when dry, rub down with fine 'wet-and-dry' sandpaper so that the antenna blends smoothly into the surface of the rim.

(8) Next, spray-paint the entire wheel and rim in its original shade, and then, when dry, carefully remove the paint from the antenna and the face of the slip-ring and finish off with 'wet-and-dry' paper. A photograph of the prepared steering wheel is shown in Plate 16.2.

(9) Finally, coat the face of the slip-ring with silicone grease, and then fit the steering wheel back in the vehicle.

(10) Now make up the copper pick-up brush and brass holder, as shown in Fig. 16.4c. The brush is made from a soldering iron tip, and has its free end carefully rounded and smoothed. The holder is made from a brass rod, drilled out to take the brush and a spring. The spring should give at least ⅜ in free movement to the brush.

(11) Finally, make up a metal clamp and use it to fix the holder to the steering column cowling, positioning the assembly so that the brush is in contact with the face of the slip-ring. Secure a solder tag behind the clamp, so that a lead can be soldered from the tag to the Veroboard panel. Check that the steering wheel moves freely, without undue

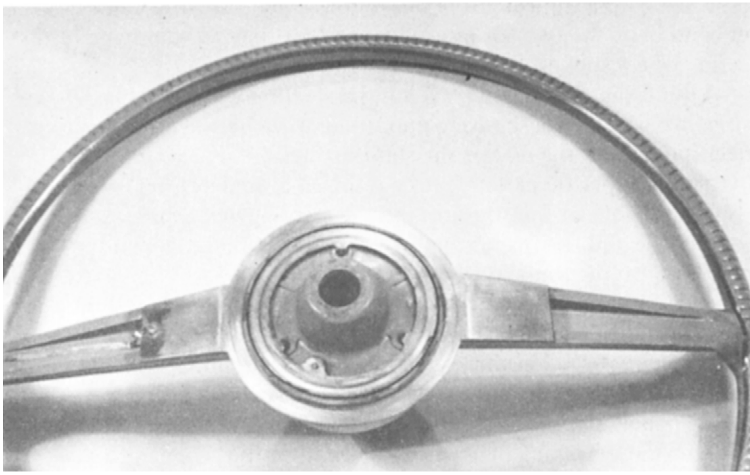


Plate 16.2

friction. This completes the construction of the antenna and pick-up assembly, and the complete unit can now be wired up and tested, as follows.

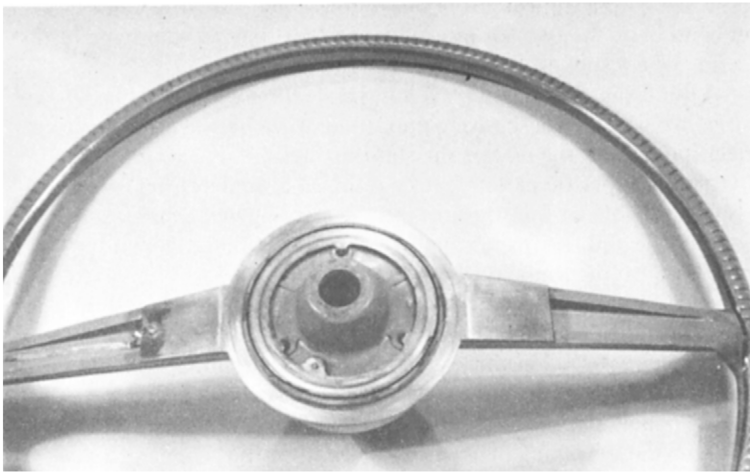
Connect the Veroboard supply leads to the car battery via S_3 and the ignition switch, as shown in Fig. 16.1. Connect a lead from hole 1a in the Veroboard to the solder tag on the pick-up brush holder. Temporarily wire a warning lamp or buzzer in series with the relay contacts, and connect across the car battery so that the lamp goes on when the relay is on. Now close S_3, turn on the ignition, and adjust R_4 so that the relay just turns on and the lamp operates; now grasp the steering wheel firmly, and check that the lamp goes off, and goes on again when the grip is relaxed; re-adjust R_4 if necessary.

Finally, give the car a test run and check that the operation is stable when the steering wheel is turned back and forth; it will probably be found that operation is slightly erratic until the car has been driven for several miles, by which time the pick-up brush and slip-ring will have become 'bedded in'. Once stable operation is established, the temporary indicator lamp can be removed and the relay contacts can be wired across the car horn switch, as shown in Fig. 16.1. The system is then complete and ready for use.

Project 17

ELECTRONIC TACHOMETER

This versatile and highly accurate electronic r.p.m. meter can be fitted to any vehicle that uses a 12 V ignition system. It works equally well



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Project 17

ELECTRONIC TACHOMETER

This versatile and highly accurate electronic r.p.m. meter can be fitted to any vehicle that uses a 12 V ignition system. It works equally well

on all 2-stroke and 4-stroke engines having from 1 to 12 cylinders, and using either conventional or electronic +ve or –ve ground ignition.

The unit is designed to give r.p.m. readings on robust and inexpensive 1 mA f.s.d. meters, and gives an accuracy equal to that of the basic meter movement, i.e., typically better than 2% of f.s.d. The accuracy is virtually unaffected by changes in battery voltage and ambient temperature, and is totally unaffected by contact breaker point bounce, switching transients, and dwell time variations.

How it works

The operating principle of the unit can be understood with the aid of the block diagram shown in Fig. 17.1. The unit's input is connected to the vehicle's contact breaker, which generates a driving waveform that has a rate directly proportional to engine r.p.m. Basically, this is a rectangular waveform with a 1:2 mark/space ratio, the waveform voltage being 12 when the points are open (mark), and zero when the points are closed (space); at the instant that the points open, however, a damped high-voltage high-frequency ringing signal is imposed on the basic waveshape via the car's ignition coil and capacitor, and this signal typically has a peak amplitude of 300 to 400 V.

To prevent the ringing high-voltage contact breaker signal damaging the semiconductor circuitry of the tachometer, therefore, the contact breaker signal is first passed through a low-pass filter, which eliminates the high-frequency high-voltage components of the basic waveform, and gives a modified low-voltage output waveform as shown. This modified waveform is then passed to a pulse inverter and sharpener, which cleans up the basic wave shape; the rising part of this waveform is then used to generate a sharp trigger pulse, which in turn is used to fire a voltage-regulated monostable multivibrator, which generates a

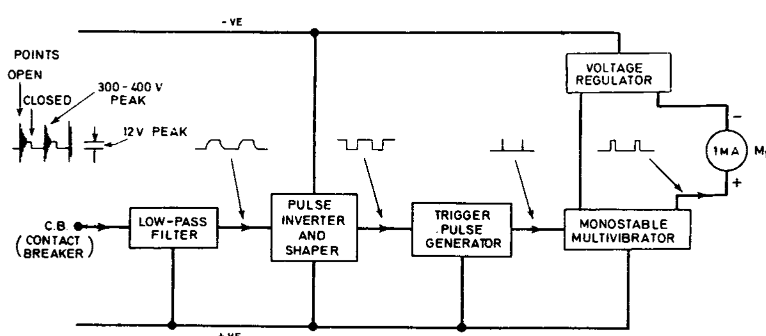

Fig. 17.1. Block diagram of the unit

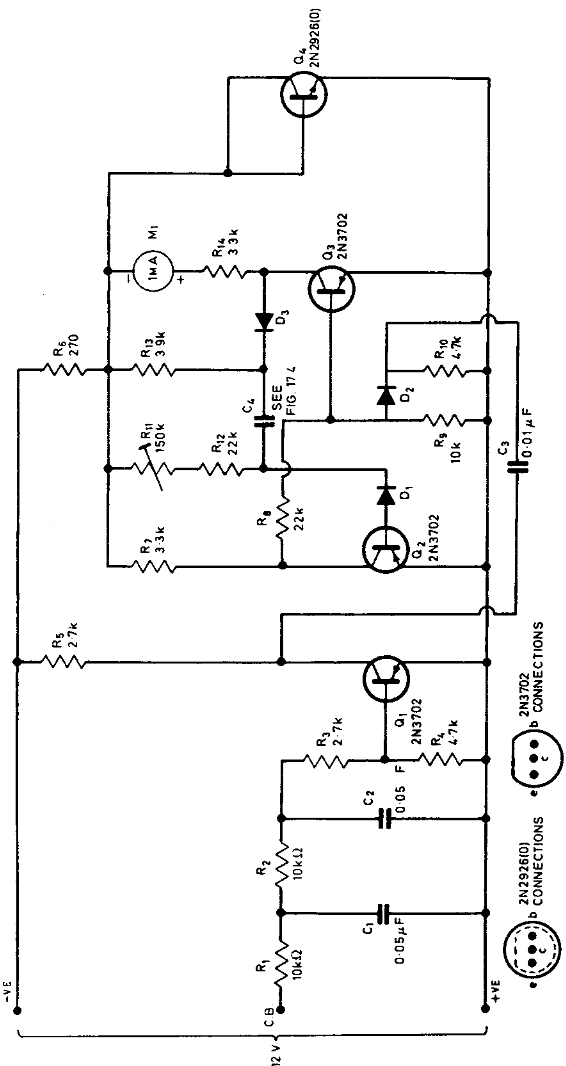

Fig. 17.2. Circuit and transistor connections of the tachometer

Components list (Fig. 17.2)

R_1	=	10 kΩ,	½ W	
R_2	=	10 kΩ,	¼ W	
R_3	=	2.7 kΩ,	¼ W	
R_4	=	4.7 kΩ,	¼ W	
R_5	=	2.7 kΩ,	¼ W	
R_6	=	270 Ω,	½ W	
R_7	=	3.3 kΩ,	¼ W	
R_8	=	22 kΩ,	¼ W	
R_9	=	10 kΩ,	¼ W	
R_{10}	=	4.7 kΩ,	¼ W	
R_{11}	=	150 kΩ,	skeleton pre-set, vertical mounting	
R_{12}	=	22 kΩ,	¼ W	
R_{13}	=	3.9 kΩ,	¼ W	
R_{14}	=	3.3 kΩ,	¼ W	
C_1	=	0.05 μF,	100 V	Mylar
C_2	=	0.05 μF,	100 V	Mylar
C_3	=	0.01 μF,	50 V	Mylar
C_4	=	0.01 μF, to 0.04 μF, 50 V Mylar (see Fig. 17.4)		
Q_1–Q_3	=	2N3702	(Texas)	
Q_4	=	2N2926,	orange coded (G.E.)	
D_1–D_3	=	general purpose silicon diodes		
M_1	=	1 mA f.s.d. moving-coil meter		
		Veroboard, hook-up wire, etc.		

pulse of fixed length and amplitude each time it is fired. The monostable pulse is then fed through a 1 mA f.s.d. meter.

Thus, a fixed pulse of current is fed through the meter each time the contact breaker closes; since the rate of contact breaker operation is directly proportional to engine speed, therefore, the mean meter current is also directly proportional to engine r.p.m. By adjusting the pulse length of the monostable multivibrator, the f.s.d. meter reading can be made to correspond to any required maximum r.p.m. reading.

The full circuit of the tachometer is shown in Fig. 17.2. R_1–R_2–C_1–C_2 make up the low-pass input filter, and Q_1 is the pulse inverter and sharpener. C_3–R_{10}–D_2 form the trigger pulse generator, and apply a pulse to the base of Q_3. The monostable multivibrator is made up of Q_2 and Q_3; Q_3 is normally off, but goes on for a pre-set period (determined by R_{11}–R_{12}–C_4) each time Q_3 is triggered, thus passing a current pulse through the 1 mA meter: D_1 is used to enhance pulse length stability, and D_3–R_{13} ensure that the pulse has a clean shape, with a short rise time. R_{11} enables the pulse length to be pre-set to give any required f.s.d. r.p.m. reading on the meter. Q_4 is wired as an 8-10 V zener diode via R_6, and ensures that the monostable's pulse amplitude remains constant in spite of variations in the car battery voltage. The unit's supply leads are connected to the car battery via the ignition switch.

The basic accuracy of the complete circuit is better than ± 1% over the battery voltage range of 10 to 15 V; this accuracy is in fact better than that of most 1 mA meters, so that in practice the instrument's accuracy is equal to that of the meter movement itself.

The accuracy is virtually independent of temperature variations, and is totally independent of the actual contact breaker waveform; since the basic contact breaker signal switches alternately between zero and full battery voltage, therefore, the unit can be used equally well on +ve and –ve ground vehicles.

Construction and use

The entire unit, less the meter, is wired up on a 3⅛ x 1⅛ in piece of Veroboard panel with 0.15 in hole spacing. Fig. 17.3 shows full constructional details on this panel. A photograph of the panel is shown in Plate 17.1.

The unit operates essentially as a frequency meter, and the value of C_4 depends on the f.s.d. meter reading required. The frequency of contact breaker operation of a 4-stroke engine is equal to r.p.m. x n/120, and of a 2-stroke equals r.p.m. x n/60, where n is the number of cylinders. Fig. 17.4 shows a graph relating frequency to r.p.m. for different types of engine, together with suitable values of

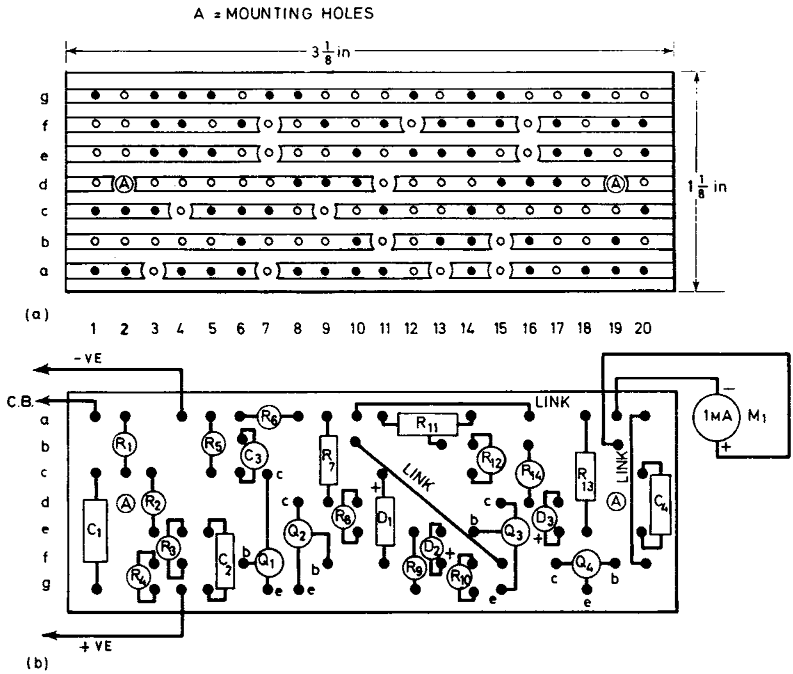

Fig. 17.3. Veroboard arrangement
(a) Copper side
(b) Component assembly on plain side

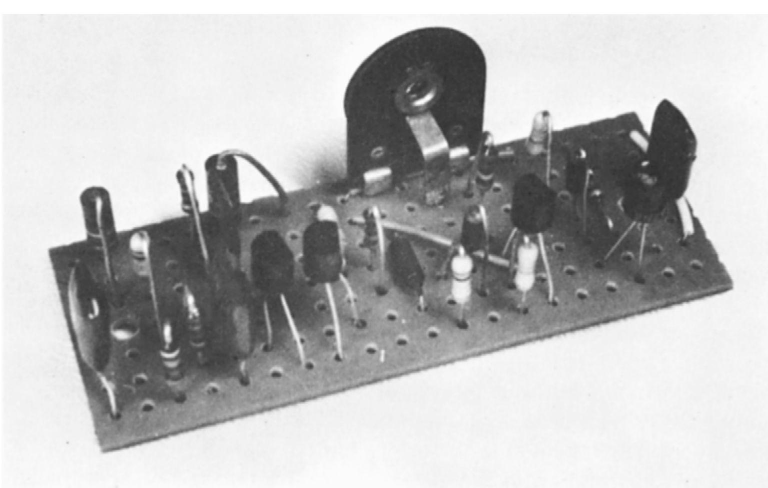

Plate 17.1

C_4. Thus, if the tachometer is needed to give an f.s.d. of 10,000 r.p.m. when used with a 4-cylinder 4-stroke, the f.s.d. frequency is 333 Hz and the C_4 value needed is 0.02 μF.

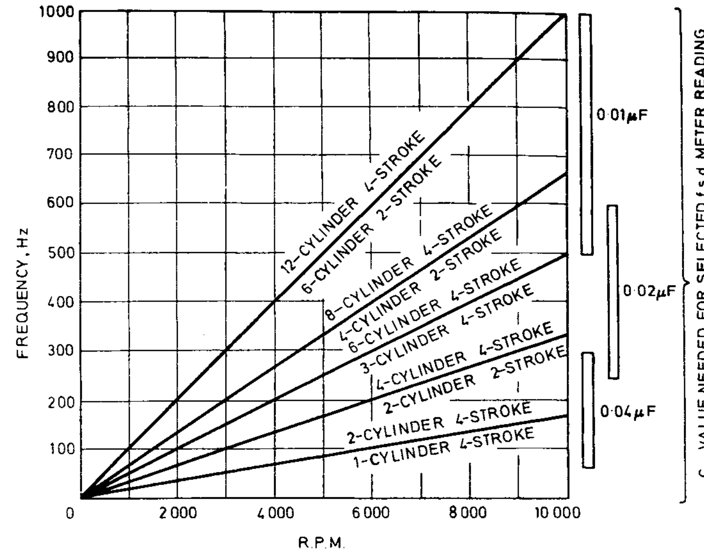

Fig. 17.4. Relationship between frequency, r.p.m., and C_4 value needed for f.s.d. tachometer readings, for different types of engine

Example: Tachometer is required to give f.s.d. reading of 10 000 r.p.m. on 4-cylinder 4-stroke. C_4 value = 0.02 μF, and f.s.d. frequency = 333 Hz

When deciding on the f.s.d. value of the tachometer, some thought should be given to the way in which the instrument is to be used, and the f.s.d. value should then be made no larger than can sensibly be used. The author's car engine, for example, can run in excess of 6,000 r.p.m., but its maximum net b.h.p. is developed at only 4,600 r.p.m., and maximum torque and b.m.e.p. at only 2,000 r.p.m.; now, the main value of a tachometer is in giving the driver an indication of optimum engine speeds for gear changing (for maximum acceleration, utilizing the engine's maximum torque and power ranges). In the above case, therefore, r.p.m. readings above 4,600 are of negligible practical value, and the tachometer has therefore been given an f.s.d. value of only 5,000 r.p.m. Details of maximum b.h.p. and torque speeds are usually available from manufacturers' handbooks.

When construction of the Veroboard unit is complete, the unit can be calibrated by connecting it to a 12 V supply, and then connecting

the output of a square wave generator, with an amplitude of at least 10 V pk-to-pk, between the unit's input and one of the supply leads; then set the generator at the required f.s.d. frequency, and adjust R_{11} to give f.s.d. on the meter. The unit is then complete and ready for use.

When using the unit in the vehicle, connect its C.B. terminal to the car's contact breaker terminal, and connect its supply leads to the car battery via the ignition switch, i.e., on –ve ground vehicles, take the –ve lead to chassis and the +ve lead to the ignition switch, and vice versa on +ve ground vehicles.

Project 18

ADD-ON EXCESS-SPEED INDICATOR

This unit is used in conjunction with the electronic tachometer circuit of Project 17, and automatically sounds an alarm or operates some other warning device whenever the vehicle exceeds a pre-selected speed limit in top gear. Over-speed trip levels can be pre-set to suit individual needs, and are selected via a multi-position switch; on the prototype unit, trip speeds of 30, 40, 50, and 70 m.p.h. are available via a 4-way selector switch.

Trip level accuracy of the circuit is about ± 0.5% over the battery voltage range 10 to 15 V, and over-speed sensitivity and backlash are equal to about 0.5% of road speed, i.e., if the unit is set to trip at speeds in excess of 70 m.p.h., the indicator goes on as soon as speed rises to 70.35 m.p.h., and goes off again when speed falls back to 70 m.p.h.

Although the unit must be used in conjunction with the circuit of Project 17, the actual 1 mA f.s.d. r.p.m. meter itself does not have to be used unless preferred, and can be simply replaced by a shorting link without affecting the operation of the excess speed indicator.

The unit operates basically as an ultra-sensitive frequency-triggered switch, which closes a relay whenever the operating frequency of the vehicle's contact breaker exceeds a pre-set limit. Its operation as an excess-speed indicator depends on the fact that an absolutely fixed ratio exists between road speed and engine r.p.m. (and thus contact breaker frequency) in any given vehicle, and is determined by (amongst other things) the ratio of the car's gear box; when the vehicle is used in top gear, therefore (as it almost invariably is when speed limits are

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exceeded), contact breaker frequency can be used to accurately represent road speed; the frequency-triggered unit can thus be set to switch precisely whenever the contact breaker frequency, and thus the top gear road speed, exceeds a pre-set limit. Relationships between road speeds and r.p.m. (and thus frequency) are usually given in vehicle manufacturers' handbooks.

How it works

The excess speed indicator circuit must be used in conjunction with the electronic tachometer circuit of Project 17; to understand its theory of operation, therefore, the two moderately simple individual circuits must be looked at as a single, fairly complex circuit. Fig. 18.1 shows the block diagram and waveforms of the single complex circuit.

Here, the vehicle's contact breaker signal is picked up and fed through a low-pass filter, and is then inverted and re-shaped via Q_1 and used to fire voltage-regulated monostable multivibrator Q_2-Q_3 via a simple trigger pulse generator. The action of the circuit at this stage is such that Q_2 is normally on, with its collector at zero volts, and Q_3 is normally off, with its collector at about 9 V –ve, these two transistors changing state for a pre-set period each time that the C.B. closes. Thus, a train of anti-phase fixed-length pulses are available at Q_2 and Q_3 collectors, and have a repetition rate proportional to contact breaker frequency, and thus r.p.m. and road speed in top gear.

In the diagram, the Q_3 collector signal is next fed to another trigger pulse generator stage, and is then used to fire a second voltage regulated monostable multivibrator, Q_5-Q_6. The action is such, however, that this second multi is driven on for its pre-set period only at the instant that the first multi switches off at the end of each of its own pulses. In this second multi, Q_5 is normally on, with its collector at zero volts, but goes off for a pre-set period each time the multi is fired. The voltage at Q_5 collector is then mixed with that of Q_2 collector, to produce a voltage across C_5 that is proportional to the peak sum of the two pulse voltage amplitudes. The C_5 voltage is then fed to a voltage triggered switch ($Q_7-Q_8-Q_9$), which drives on relay *RLA* whenever the C_5 voltage exceeds a certain value.

Now, the important point here is that Q_2 and Q_5 collectors are normally at zero volts, but that Q_2 collector switches –ve for a fixed period each time the contact breaker closes, and that at the end of this period Q_2 collector returns to zero and causes Q_5 to go –ve for another pre-set period. Thus, if the first pulse has a duration of (say) 3 ms, and the second has a duration of 7 ms, a total pulse length of 10 ms is developed each time the contact breaker closes. Fig. 18.2 shows how this simple fact is utilized to operate the indicator (relay) at C.B. speeds in excess of 100 Hz, i.e., at C.B. periods less than 10 ms.

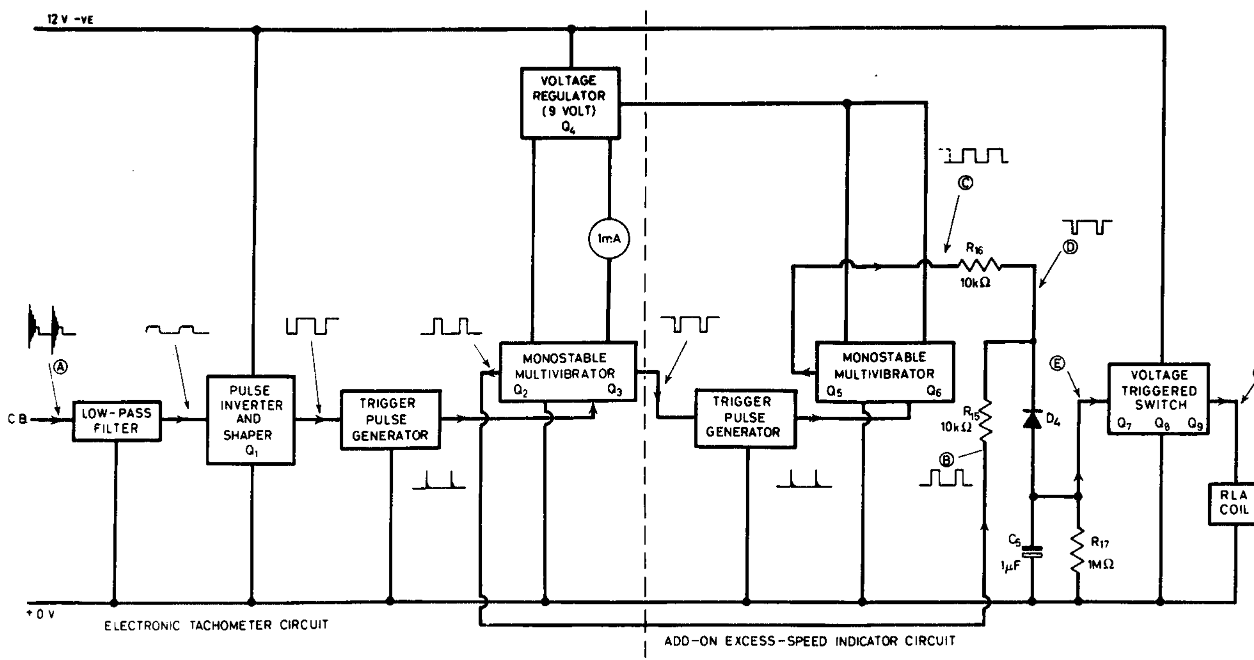

Fig. 18.1. Block diagram and waveforms of the complete excess-speed indicator

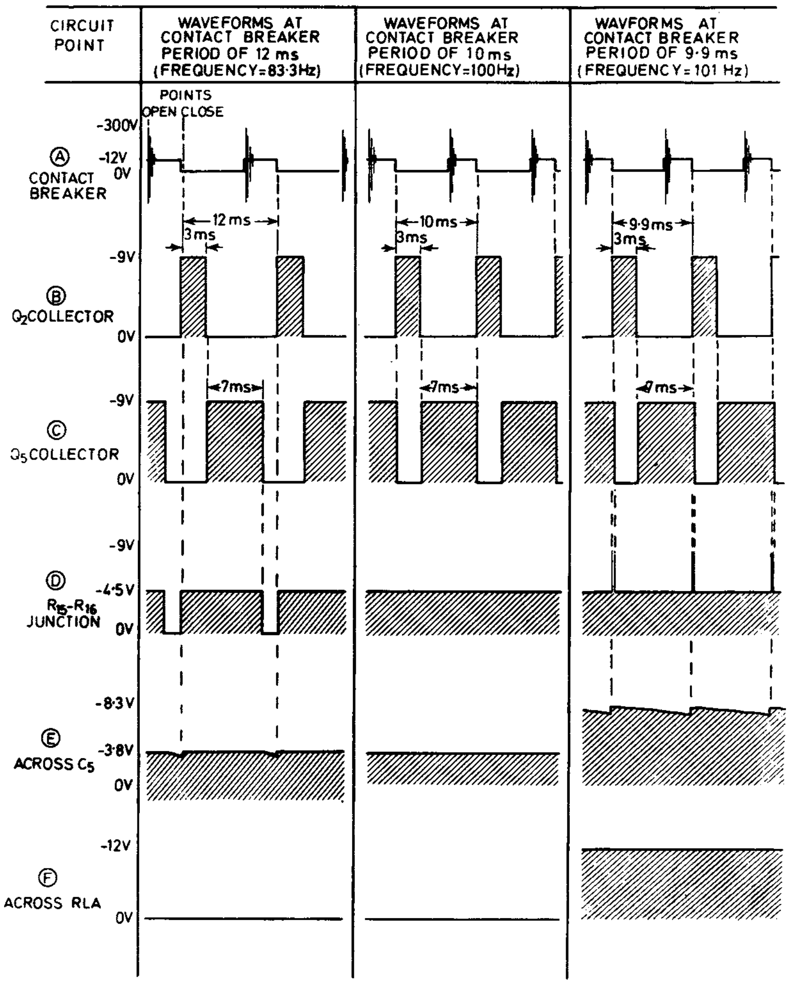

Fig. 18.2. Typical circuit waveforms of Fig. 18.1 when the excess-speed indicator is set to trigger at contact breaker frequencies above 100 Hz, i.e., at periods below 10 ms

Look first at the case where the C.B. period is well above 10 ms, at 12 ms (= 83.3 Hz). In this case Q_2 goes off at the moment that the C.B. closes, and Q_5 is on, giving a potential of about 4.5 V at point D (by the potential divider action of R_{15} and R_{16}). As soon as Q_2 goes on again after 3 ms, Q_5 goes off for 7 ms, again giving a potential of 4.5 V at point D. At the end of this period, both Q_2 and Q_5 are on for a period of 2 ms (until the C.B. closes again), giving a potential of zero at point D. Thus, C_5 (point E) charges to a peak potential of 3.8 V (= 4.5 V, minus the forward volt drop of D_4) under this condition, and fails to turn on the relay (point F) via the voltage triggered switch (which needs a voltage in excess of 4.5 V to fire).

Now look at the case where the C.B. period is precisely 10 ms, giving a frequency of 100 Hz. Here, the total period of the twc pulses exactly coincides with the period of the contact breaker, so either Q_2 is off and Q_5 is on, or vice versa, at all times, and a steady potential of 4.5 V is therefore developed at point D. A potential of 3.8 V is again developed at point E, therefore, and the relay is again off.

Finally, look at the case where the two monostable pulses exceed the C.B. period by 0.1 ms, i.e., where the C.B. period is 9.9 ms, at a frequency of 101 Hz. In this case both Q_2 and Q_5 are off together for a period of 0.1 ms each time the contact breaker closes; in this brief period the potential at point D rises to 9 V, and causes C_5 to charge to 8.3 V; the voltage triggered switch is thus driven on under this condition, and causes the relay to operate. Note here that the total monostable pulse periods only have to exceed the C.B. period by a minute amount to cause the relay to switch from fully off to fully on; the circuit is thus exceptionally sensitive. Also note that, by adjusting the pulse length of Q_5, the circuit can be made to trip at any required frequency.

The practical circuit of the add-on excess-speed indicator is shown in Fig. 18.3. C_6–D_6–R_{25} form the trigger pulse generator. The monostable multi is built around Q_5 and Q_6; the circuit is temperature stabilized via D_5, and is powered from the voltage regulator of the electronic tachometer; the monostable thus develops a pulse of very stable duration. The pulse duration is determined by the value of C_7, which is selected on test, and can be pre-set via switch-selected trimmer resistors R_{20}–R_{23}.

The voltage triggered switch, Q_7–Q_9, operates in the differential mode. Here, a fixed reference potential of 4.5 V is applied to Q_7 base, and the C_5 voltage is applied to the base of Q_8; Q_8 collector current is fed to the base of common emitter amplifier Q_9, which has relay *RLA* connected as its collector load. Thus, if the C_5 voltage is appreciably less than 4.5 V, Q_7 is biased on and reverse biases the base-emitter junction of Q_8; Q_8, Q_9, and the relay are thus fully off under this condition. When, on the other hand, the C_5 voltage is appreciably above 4.5 V, Q_8 becomes forward biased, and thus drives Q_9 and the relay on.

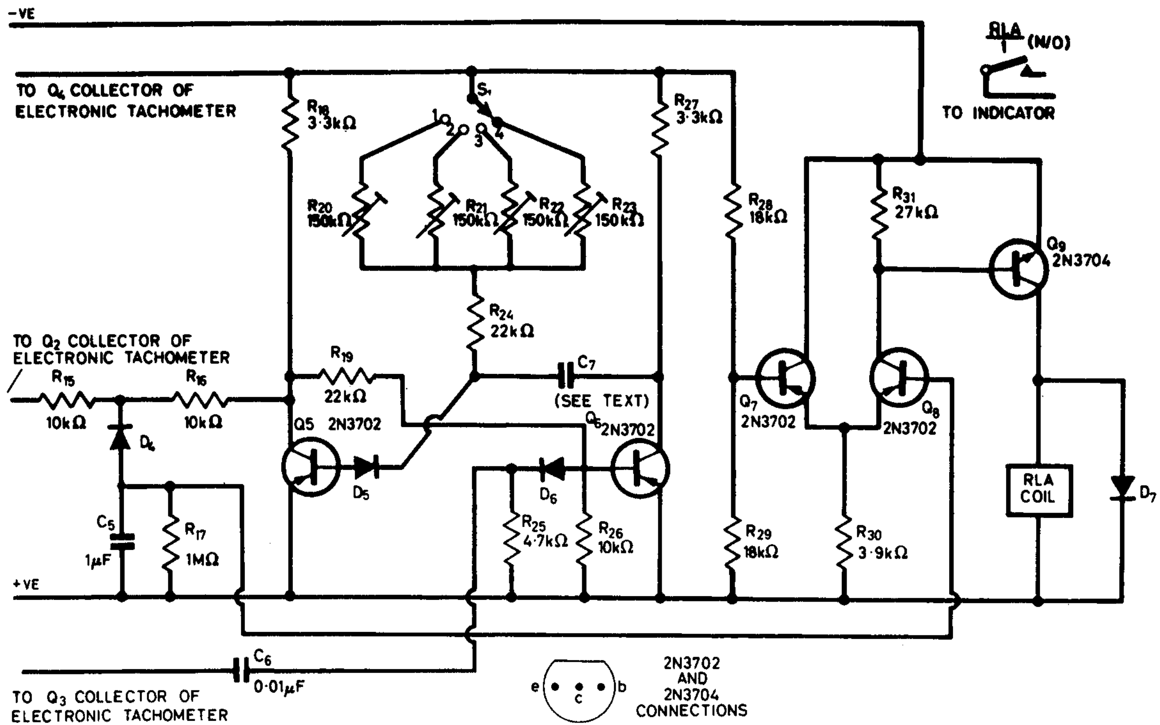

Fig. 18.3. Circuit and transistor connections of the add-on unit

Components list (Fig. 18.3)

R_{15}	=	10 kΩ,	¼ W	
R_{16}	=	10 kΩ,	¼ W	
R_{17}	=	1 MΩ,	¼ W	
R_{18}	=	3.3 kΩ,	¼ W	
R_{19}	=	22 kΩ,	¼ W	
R_{20}, R_{21}, R_{22}, R_{23}	=	150 kΩ,	skeleton pre-sets	
R_{24}	=	22 kΩ,	¼ W	
R_{25}	=	4.7 kΩ,	¼ W	
R_{26}	=	10 kΩ,	¼ W	
R_{27}	=	3.3 kΩ,	¼ W	
R_{28}	=	18 kΩ,	¼ W	
R_{29}	=	18 kΩ,	¼ W	
R_{30}	=	3.9 kΩ,	¼ W	
R_{31}	=	27 kΩ,	¼ W	
C_5	=	1 μF,	12 V	electrolytic
C_6	=	0.01 μF,	50 V	Mylar
C_7	=	50 V Mylar, see text		
Q_5–Q_8	=	2N3702	(Texas)	
Q_9	=	2N3704	(Texas)	
D_4–D_7	=	general purpose silicon diodes		
RLA	=	any 12 V relay with a coil resistance greater than about 240 Ω, and with one or more sets of N/O contacts		
S_1	=	single-pole, 4-way range switch		
		Veroboard, hook-up wire, etc.		

Construction and use

The major part of the add-on excess-speed indicator is built, less *RLA*, S_1, and trimmer resistors R_{20} to R_{23}, on a 2⅞ x 1⅛ in piece of Veroboard panel with 0.15 in hole spacing. Fig. 18.4 shows component assembly and wiring details on this panel.

C_7 has a value of roughly 2 to 5 times the value of C_4 (in the tachometer circuit), its precise value being selected on test, as follows.

First, wire up the electronic tachometer circuit of Project 17, connect meter M_1 in place (either permanently or temporarily), and adjust the unit to give a sensible f.s.d. r.p.m. reading, as described in Project 17. When the adjustment is complete, the meter can be either left permanently in place, or can be replaced with a shorting link.

Next, wire up the complete add-on excess-speed indicator circuit (including *RLA*, S_1, and R_{20}–R_{23}), as shown in Fig. 18.4, giving C_7 a value roughly 2 to 5 times greater than that of C_4, and connect the unit to the tachometer circuit as indicated. A photograph of the completed panel is shown in Plate 18.1. Now consult the car manufacturer's handbook, and establish the r.p.m. values at which the unit is required to trip at different top gear road speeds; convert these values to frequency, using the formulae given in Project 17. In the prototype unit, selected trip speeds are 30, 40, 50, and 70 m.p.h.

Now connect the power leads of the complete unit (two on the tachometer, two on the add-on circuit) to a 12 V supply, and connect the output of a square-wave generator, with an amplitude of at least 10 V pk-to-pk, between the tachometer's C.B. terminal and one of the supply leads. Turn S_1 to the *1* position, set R_{20} at mid-value, and give the complete unit a functional test by varying the generator frequency to check that the relay triggers on and off correctly.

Once the unit is seen to be functioning correctly, set the generator to the lowest required trip frequency (i.e., equal to 30 m.p.h. in the

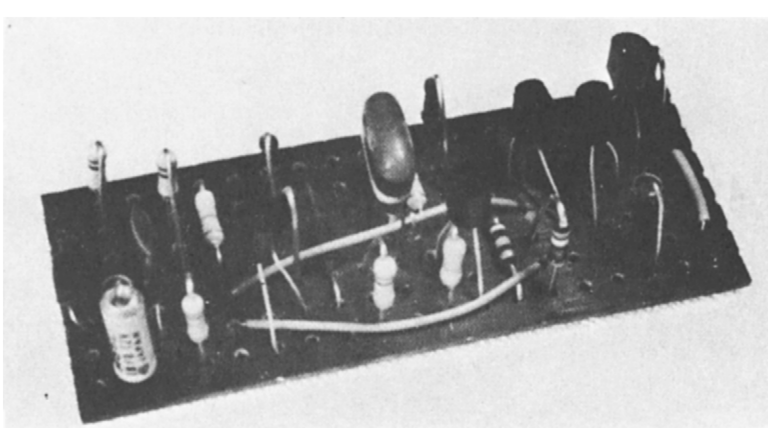

Plate 18.1

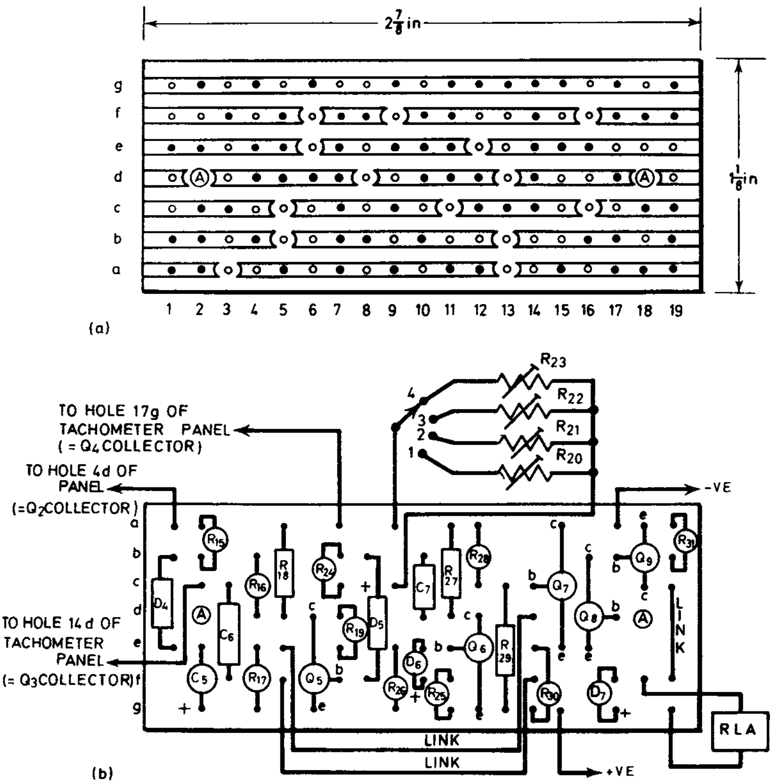

Fig. 18.4. Veroboard arrangement
(a) Copper side
(b) Component assembly and wiring on plain side

case of the prototype unit), and adjust R_{20} so that the relay just turns on at this frequency; R_{20} should be set in the range half-to-full value under this condition; if the R_{20} value is set considerably below half value under this condition, increase the value of C_7 and re-adjust R_{20}; if, on the other hand, the relay does not trip even when R_{20} is set to full value, reduce the value of C_7 and re-adjust R_{20} until the correct operation is obtained.

Once the above adjustment is complete, turn S_1 to the *4* position, set the generator to the highest required trip frequency (i.e., equal to 70 m.p.h. in the case of the prototype unit), and adjust R_{23} so that the relay just turns on at this frequency; if the relay can not be made to trip at this frequency, even when R_{23} is adjusted to minimum value, increase the value of C_7, and re-check the trip adjustment of the unit in the *1* and *4* positions of S_1, until a C_7 value is found at which both

adjustments can be made satisfactorily. In practice, the trimmer resistors enable a maximum-to-minimum trip frequency range of 6:1 to be accommodated using a single C_7 value, so little difficulty should actually be experienced in establishing a satisfactory C_7 value.

Once the C_7 value is finalized, complete the adjustments of R_{20} and R_{23} in the different S_1 positions, to give relay operation at the four selected frequencies. The unit is then complete and ready for use, and can be installed in the vehicle.

When using the unit in the vehicle, connect the tachometer C.B. terminal to the car's contact breaker terminal, connect the two +ve leads together and the two –ve leads together, and connect these supply leads to the car battery via the ignition switch, i.e., on –ve ground vehicles, take the –ve leads to chassis and the +ve leads to the ignition switch, and vice versa on +ve ground vehicles. The normally open (NO) relay contacts can be connected to a buzzer or a panel light, to give an audio or visual over-speed indication.

Project 19

SELF-REGULATING BATTERY CHARGER

This self-regulating device charges a 12 V car battery at a rate of 3 to 4 A when the accumulator is 'flat', but then automatically reduces the charge to a trickle rate when the battery voltage reaches its 'fully charged' value. The unit thus eliminates the danger of overcharging a battery, and eliminates the need for the owner to occasionally check the battery state when it is connected to the charger. If, in fact, a battery is permanently connected to the charger, it will automatically be maintained in a permanent state of full charge, but will never be overcharged.

How it works

The full circuit of the charger is shown in Fig. 19.1. Transformer T_1 and bridge rectifier D_1–D_4 step down and rectify the mains line voltage, and apply a charge current to the battery via limiting resistor R_1 and silicon controlled-rectifier SCR_1; SCR_1 gate current is derived from the rectified a.c. line via D_5 and R_6. SCR_2 is wired between the

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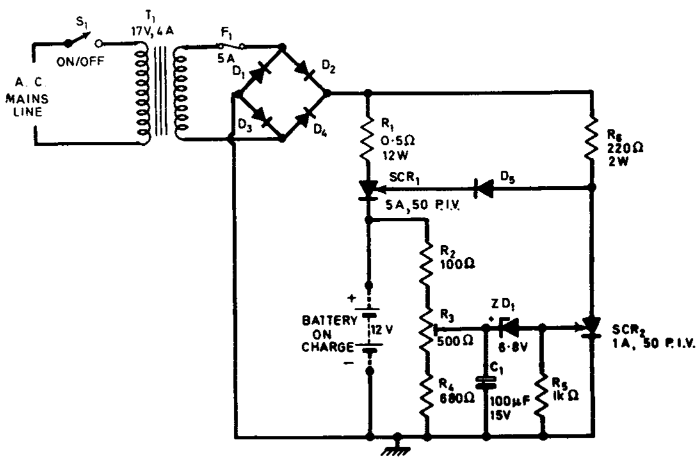

Fig. 19.1. Circuit of the battery charger

Components list (Fig. 19.1)

R_1	=	0.5 Ω, 12 W wire-wound (= 3 off 1.5 Ω, 4 W, in parallel)
R_2	=	100 Ω, ½ W
R_3	=	500 Ω, 1 W wire-wound pre-set pot
R_4	=	680 Ω, ½ W
R_5	=	1 kΩ, ½ W
R_6	=	220 Ω, 2 W
C_1	=	100 μF, 15 V electrolytic
S_1	=	on/off switch
F_1	=	5 A fuse or re-settable trip
T_1	=	17 V, 4 A (approx.) battery charger transformer
D_1–D_4	=	5 A, 50 p.i.v. silicon rectifiers, or one 5 A, 20 V bridge rectifier
D_5	=	any 100 mA, 25 p.i.v. silicon diode
SCR_1	=	any 5 A, 50 p.i.v. (or greater) s.c.r.
SCR_2	=	any 1 A, 50 p.i.v. (or greater) s.c.r.
ZD_1	=	any 6.8 V, 5%, 400 mW zener diode

D_5–R_6 junction and ground, and has its gate current derived from the battery via potential divider R_2–R_3–R_4 and smoothing capacitor C_1 and zener diode ZD_1; R_3 is adjusted to that SCR_2 is gated on only when the battery voltage reaches a 'fully charged' value of, say, 13 V.

Thus, when a battery is initially placed on charge, its terminal voltage is inevitably less than 13 V, so zero gate current flows to SCR_2, and SCR_2 is thus off. SCR_1 is therefore gated on via D_5 and R_6 at the start of each half cycle of bridge-rectified voltage, and high charge currents flow to the battery via R_1 and SCR_1; R_1 limits charge currents

to safe values of 3 to 4 A over the approximate battery voltage range 10 to 13 V.

As the battery charges up, its terminal voltage rises in proportion to the state of charge, and eventually reaches a value of (say) 13 V at full charge. At this stage, sufficient voltage is developed at the slider of R_3 to cause zener diode ZD_1 to conduct, and SCR_2 is thus gated on. As SCR_2 goes on, its anode pulls the D_5-R_6 junction towards ground volts, and thus removes the gate current to SCR_1. SCR_1 thus turns off, and the battery charge current reduces to zero.

Once the battery charge current is reduced to zero, the battery terminal potential slowly decays back below 13 V, and when it has fallen by a few tens of millivolts SCR_2 goes off again and turns SCR_1 back on, to apply a recharge current to the battery and bring its terminal voltage back to 13 V. This 'cycling' process then repeats *ad infinitum,* so that the battery is effectively trickle charged so that its terminal voltage is maintained at 13 V. The sensitivity of the circuit is such that the battery terminal voltage is then automatically kept within a few tens of millivolts of the value pre-set by R_3.

Construction and use

Constructional details of the unit are in no way critical, and it can be wired up directly from the circuit diagram. If individual silicon rectifiers are used for D_1-D_4, however, they must be mounted on suitable heat sinks, as also must be SCR_1. Fuse F_1 can be replaced by a resettable 5 A mechanical trip, if preferred. A 0-4 A charge current meter can be wired in series with R_1, if required, or, alternatively, an indication of charge current can be obtained by connecting a voltmeter across R_1, which develops a potential of 0.5 V per amp of current.

When construction is complete, turn R_3 slider down towards R_4, connect a fully charged battery in place in the polarity shown, and switch the unit on. Check that the unit passes a charge current of roughly 3 A; if currents are greatly above this, increase the value of R_1 to bring them to roughly the right value.

Now slowly adjust R_3 slider up towards R_2 until a point is reached where the charge current just drops to zero or a low trickle value. Now place a high current lamp or other load across the battery terminals, so that the battery voltage falls by a few tens of millivolts, and check that (probably after a short delay) the charge current switches to 3 A again. Now remove the lamp load, and check that (probably after a delay of several minutes) the unit again reverts to trickle charge. If satisfactory, the unit is now complete and ready for use, and can be connected up to a 'flat' battery.

When setting up and using the charger, it may be found that, instead of the charge rate falling abruptly from full to trickle as the battery reaches full charge, the charge current in fact falls briefly from full rate to half rate, and then falls to trickle rate some time later. If it does occur, this penomenon is due to slight unbalances in the D_1–D_4 bridge rectifier diodes, and is nothing to worry about.

Project 20

ELECTRIC DRILL SPEED-CONTROLLER

This project is intended for use in the garage, and enables the speed of any electric power drill to be smoothly varied all the way from zero to maximum. The unit is of great value when carrying out sanding, drilling, or polishing operations on the car.

How it works

The circuit of the drill speed-controller is shown in Fig. 20.1. The heart of the unit is the device marked as Q_1; this device is known under a variety of names, but will be referred to here as a 'quadrac'. The basic characteristics of the quadrac are as follows.

The quadrac is a solid-state high voltage power switch which is either open circuit (o/c) or short circuit (s/c) between main-terminal-1 (MT1) and main-terminal-2 (MT2). These terminals can be connected to any polarity of supply voltage, so the device can act as a switch to both d.c. and a.c. loads.

The quadrac is normally o/c between its two main terminals, and thus acting as an o/c switch, but it can be made to act as an s/c switch by applying a suitable trigger voltage or pulse to its gate terminal. This gate signal can be of either polarity, and must have an amplitude of about 35 V; it only needs to be applied for a few microseconds, however, to ensure full turn on of the quadrac. Once the quadrac has been turned on, the gate loses control, and the device stays on so long as its main currents (between MT1 and MT2) exceed a fairly low 'holding' value; once the main current falls below this value the device automatically turns off again, and remains off until it is triggered back on by a gate pulse.

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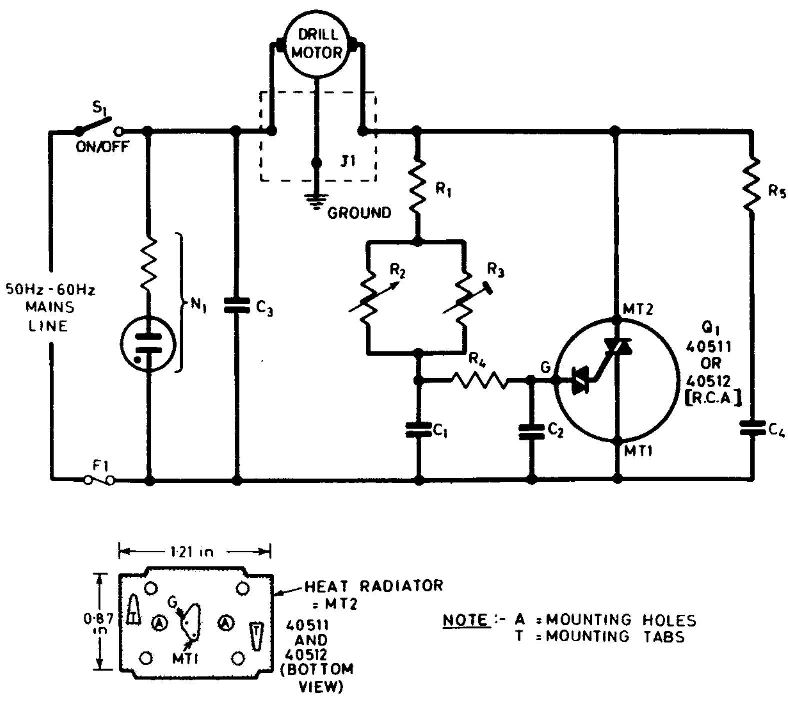


Fig. 20.1. Circuit and quadrac connections of the drill speed-controller

Components

120 V version

R_1	=	2.2 kΩ,	½ W
R_2	=	150 kΩ,	linear pot., ½ W
R_3	=	250 kΩ,	skeleton pre-set, vertical mounting
R_4	=	15 kΩ,	½ W
R_5	=	100 Ω,	½ W
C_1	=	0.1 μF,	200 V paper or Mylar
C_2	=	0.1 μF,	100 V paper or Mylar
C_3	=	0.1 μF,	200 V paper or Mylar
C_4	=	0.22 μF,	200 V paper or Mylar
Q_1	=	40511	(R.C.A.)
S_1	=	5 A	on/off switch
F_1	=	5 A	fuse
N_1	=	120 V	neon lamp, with ballast resistor
J_1	=	3-pin,	5 A socket
Drill motor	=	up to 240 W (2 A) or up to 600 W (5 A) if Q_1 is fitted to additional heat sink	

240 V version

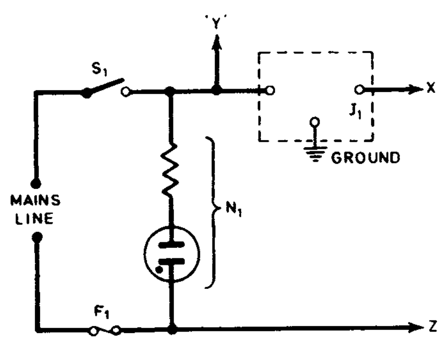
R_1	=	3.3 kΩ,	½ W
R_2	=	250 kΩ,	linear pot., 1 W
R_3	=	500 kΩ,	skeleton pre-set, vertical mounting
R_4	=	15 kΩ,	½ W
R_5	=	100 Ω,	½ W
C_1	=	0.1 μF,	400 V paper or Mylar
C_2	=	0.1 μF,	100 V paper or Mylar
C_3	=	0.1 μF,	400 V paper or Mylar
C_4	=	0.22 μF,	400 V paper or Mylar
Q_1	=	40512	(R.C.A.)
S_1	=	5 A	on/off switch
F_1	=	5 A	fuse
N_1	=	240 V	neon lamp, with ballast resistor
J_1	=	3-pin,	5 A socket
Drill motor	=	up to 480 W (2 A) or up to 1200 W (5 A) if Q_1 is fitted to additional heat sink	

Thus, when the quadrac is used with an a.c. supply, and is triggered on via the gate during the early part of a half cycle, it remains on until the end of that half cycle, even though the gate signal may be removed in the meantime; at the end of that half cycle, however, the quadrac switches off automatically as its MT1 to MT2 voltage (and thus current) falls momentarily to zero.

Having explained the basic action of the quadrac, we can now look at the circuit of Fig. 20.1 to see how the device is used. Here, the electric drill is connected in series with the quadrac via socket J_1, and the combination is wired across the mains power line via S_1 and F_1. R_1–R_2–R_3–C_1 and C_2 act together as a variable phase shift network, and enable the a.c. signal on Q_1 gate to be effectively delayed, relative to that on MT2, by any amount between about 5 and 170 degrees, depending on the setting of R_2.

Suppose, then, that R_2 is set for minimum phase delay. In this case Q_1 is off at the start of each half cycle, and the full line voltage is applied to the phase delay network. Five degrees after the start of each half cycle, however, the Q_1 gate voltage rises to 35 V, and Q_1 is triggered on and self-latches, thus remaining on for the remaining 175 degrees of each half cycle: The quadrac is thus on (acting like an s/c switch) for almost the full duration of each half cycle, so the drill therefore operates at maximum power.

Suppose, on the other hand, that R_2 is set for maximum phase delay. Q_1 is again off at the start of each half cycle, but in this case the gate potential does not rise to 35 V until 170 degrees after each



half cycle has started; Q_1 is therefore only turned on for the final 10 degrees of each 180 degree half cycle, and very little of the available line power is therefore applied to the drill, which thus operates at low speed.

Thus, the drill power can be varied all the way from full to near-zero by varying the phase delay via R_2. In this circuit, R_5 and C_4 prevent incorrect triggering of the quadrac due to an effect known as

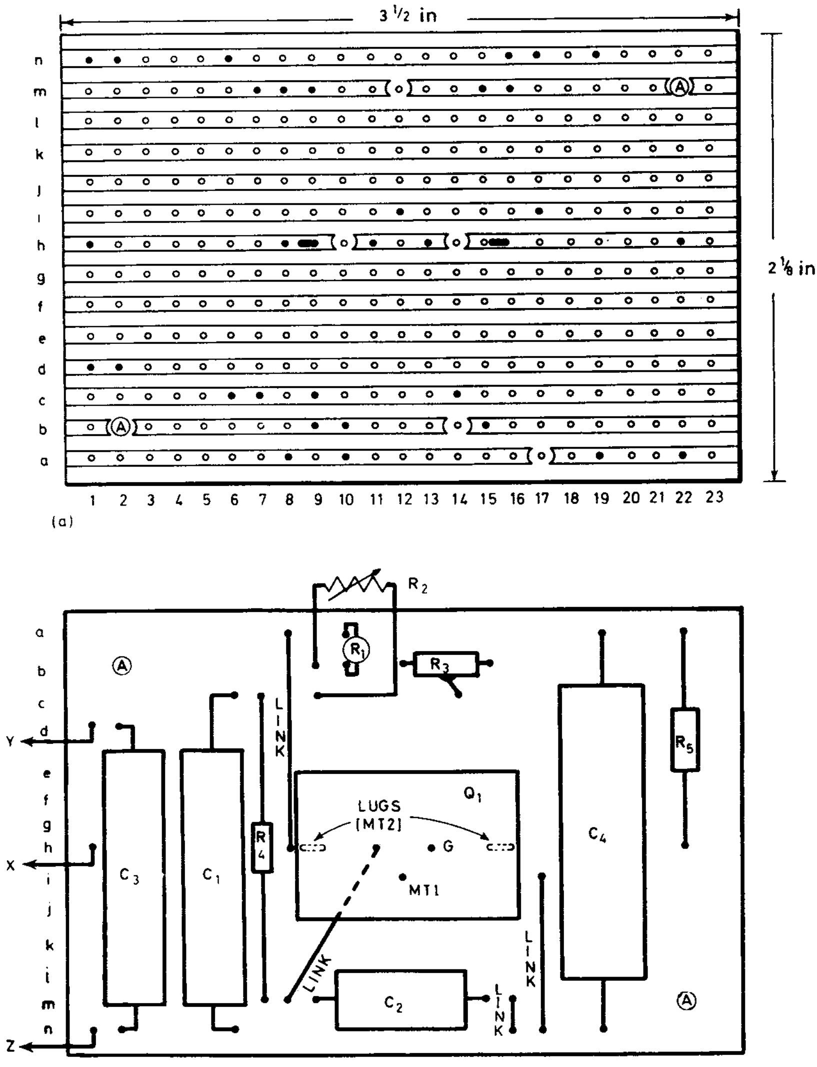


Fig. 20.2. Veroboard arrangement
(a) Copper side
(b) Component assembly and wiring on plain side

'commutating', and C_3 helps to keep high frequency switching transients (from the quadrac) out of the mains power lines. Neon lamp N_1 gives a visual indication when the unit is connected to the mains line with S_1 closed.

Construction and use

The unit can be used with either 50 Hz or 60 Hz, 120 V or 240 V mains power lines. The specified quadracs are supplied with integral heat radiators, and can handle r.m.s. currents of about 2 A without extra heat sinking, or of about 5 A with additional heat sinking. Thus, the unit can control drill powers up to 240 W and 600 W respectively on 120 V lines, and up to 480 W or 1200 W on 240 V lines.

Constructional details of the unit are in no way critical, and can be varied to satisfy individual tastes. The prototype unit, however, uses Q_1 without additional heat sinking, and is assembled in a 6 x 4 x 2½ in metal case, as shown in Plates 20.1 and 20.2, with Q_1–R_1–R_3–R_4–R_5–C_1–C_2–C_3–C_4 mounted on a 3½ x 2⅛ in Veroboard panel with 0.15 in hole spacing, as shown in Fig. 20.2. This panel is mounted over R_2, and is secured above it by two ¾ in long insulated spacers.

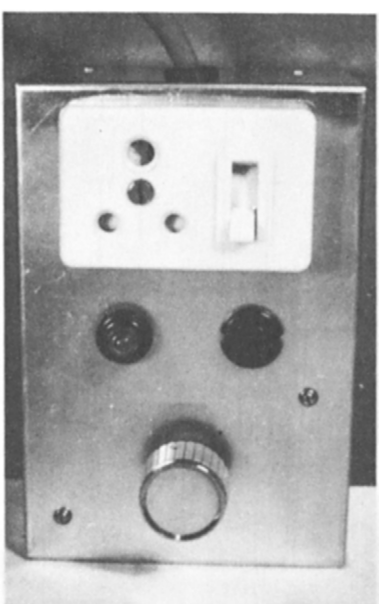


Plate 20.1

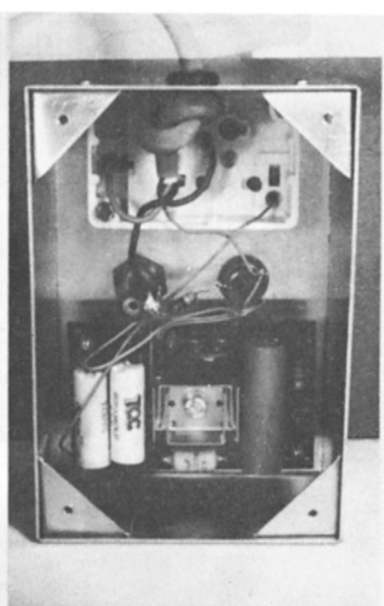


Plate 20.2

When construction of the unit is complete, set R_3 at mid-value, connect the electric drill via J_1, connect the unit to the mains line, and switch on via S_1. Check that neon lamp N_1 lights up, then, with R_2 set to maximum value (for minimum speed), adjust R_3 to give a near-zero drill speed. Now check that the drill speed can be smoothly varied from near-zero to maximum via R_2: Check that Q_1 does not overheat, but remember that Q_1 is 'live', so switch off before touching the quadrac; if overheating does occur, it will be necessary to fix Q_1 to an additional heat sink. The unit is then complete and ready for use.

20 SOLID STATE PROJECTS
FOR THE CAR AND GARAGE

Eighteen of the twenty projects described are intended for use in the car and two for the garage. The circuits for the car range from those that warn of danger, such as from ice or overheating, to those that ease the driver's task and allow him to concentrate on driving: for example the windscreen wiper controller and the automatic sidelight switch.

The two projects for the garage are valuable supplements to the use of a car – a self-regulating battery charger and a speed controller for an electric drill.

All the projects can be built easily and, like the author's earlier book '20 Solid State Projects for the Home', make use of internationally available components.

Clear descriptions of the operation and construction of each circuit, together with the detailed lists of components, make each project simple, and the book will be useful not only to the car owner, but also to students and apprentices seeking a grounding in the operation of electronic circuits. Professional electronics engineers will find much to interest them.

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